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RECENT DISCOVERIES IN RADIATION AND THEIR SIGNIFICANCE.

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THERE are times when the atmosphere seems to be fairly saturated with the spirit of scientific discovery. Such a time existed during the opening years of the nineteenth century when John Dalton was putting the atomic theory of matter upon an experimental rather than upon the purely speculative foundation upon which it had previously rested; when Count Rumford, an American by birth, was laying the corner-stone of the modern mechanical theory of heat, in accordance with which heat consists in the vibratory motion of the particles of which matter is composed; when Thomas Young was forging the final links in the chain of proof that light consists in the wave motion of some all-pervading medium, the ether.

It is not a little interesting that the opening years of the twentieth century have also been marked in no less a degree than those of its predecessor by epoch-making discoveries in physics. Most of this new activity has been grouped about the general subject of radiation, discoveries of new rays having followed one another in such rapid succession that it is difficult even for a physicist to keep posted about them all. As a result of these discoveries important progress has been made toward the solution of one of the most fundamental questions with which science has to deal, viz., the question as to the nature and the constitution of matter.

The Discovery of X-rays.

The discovery of X-rays is to be regarded as the starting point of this epoch of investigation upon radiation. It was in the Christmas

season of 1895 that Professor Röntgen of Wurzburg, Germany, exhibited to the Physical Society of Berlin the first X-ray photographs. These photographs showed that from a vacuum bulb in which an electrical discharge was passing some sort of radiation was emitted, which was like light in that it produced an effect upon the photographic plate, but was unlike light, first, in that it was wholly invisible, and, second, in that it was able to pass easily through many substances which are perfectly opaque to ordinary light, such, for example, as cardboard, wood, leather and, notably, the flesh of the human hand. This discovery would probably have attracted little attention outside of scientific circles had it not been for this last-mentioned remarkable property, but the idea of obtaining photographs of the skeleton of a living being was so startling, so uncanny, at that time, to the average mind, that the discovery took to itself wings and within two weeks had set the whole world agog. Scores of scientists in all countries dropped at once their pending researches and began to experiment upon these strange new rays which Röntgen had named X-rays because they were such a completely unknown quantity. A surprisingly small amount of new knowledge concerning the nature of X-rays themselves resulted from all this research. The X-rays are almost as much of an unknown quantity to-day as they were when Röntgen made his first announcement. As is so often the case, it was in unexpected directions that this wave of experimentation upon X-rays bore fruit. The discovery of radio-activity was not the least important result of this activity. It came about in this way.

The Discovery of Radio-activity.

It was noticed that an exhausted bulb which is emitting X-rays under the influence of electrical discharges is always aglow with a peculiar greenish-yellow light which is commonly known as fluorescent light. Now it had long been known that there are some natural substances, notably the mineral uranium and its compounds, which possess a similar property of emitting this yellowish-green light not only when they are in a vacuum tube through which electrical discharges are passing, but also when they are exposed to the invisible radiation from the sun, that is, to the so-called actinic or ultra-violet rays which are chiefly responsible for the effects which sunlight produces upon photographic plates. It accordingly very naturally occurred to some scientists that the X-rays might perhaps be due to this fluorescent light which came from a vacuum bulb, rather than to any immediate influence of the electrical discharge, and, if so, that they ought to be emitted not simply by a vacuum tube, but also by uranium when exposed to sunlight. It was in 1896, within a year of the discovery of X-rays, that Henri Becquerel, the fourth illustrious possessor of that illustrious name, devised some experiments to test this inference. His method

was to expose uranium to strong sunlight for a long time, and then to notice whether a photographic plate, which was wrapped up carefully in perfectly opaque paper and placed beneath the uranium, received any impression from it. He found that it did; but he further found that the exposure of the uranium to sunlight was altogether unnecessary; that the uranium itself in a perfectly dark room would affect, in the course of ten or twenty days, a photographic plate from which it was separated both by opaque black paper and by a thin sheet of metal. In fact he obtained in this way a radiograph of a metallic object similar in all respects to the pictures which Röntgen had obtained with X-rays. This showed, in the first place, that the fluorescent light had nothing whatever to do with the production of the photograph, but it showed also something much more important than this, namely, that *the mineral uranium is all the time spontaneously emitting rays of some sort, which are capable of penetrating opaque objects in just the way the X-rays do.*

This discovery, which has been one of the most fruitful in the history of science, is immediately due to the accident of a few cloudy days in Paris, during which Becquerel, since he could not expose his uranium to sunlight, set away his plate with the uranium on the top of it, to wait for fair weather. When the fair weather returned and he was ready to continue his experiments, it fortunately occurred to him that it might be worth while to develop the plate upon which the uranium had rested to see if anything had happened to it. The discovery of radio-activity was the result. Those who recall the story of the discovery of photography will remember that it was made quite as accidentally and under quite similar circumstances.

Becquerel further found that the rays emitted by uranium are also emitted by all uranium compounds. He therefore named them *uranium rays.* Another property which he found that the rays possessed, in addition to that of affecting a photographic plate, was the important property of rendering a gas through which they pass a conductor of electricity, or, to state the same thing in another way, the property of discharging any electrified body which is brought into their neighborhood.

The Discovery of Radium.

It was but a few months after this that Madame Curie, one of the few women who has attained eminence in the pursuit of science, and who together with her husband, with whom most of her work has been done, deserves a large share of the credit for our present knowledge of radium, set about investigating all the then known elements to see if any of the rest of them possessed this remarkable property which Becquerel discovered in uranium. She found that one, and but one, of the remainder of the elements, namely, thorium, the element which is one of the chief constituents of Welsbach mantles, was capable of pro-

ducing precisely the same effects which Becquerel had discovered with uranium. After this discovery the rays from all this class of substances began to be called *Becquerel rays,* in honor of Becquerel, and all substances which emitted such rays were called *radio-active* substances.

But in connection with this investigation, Madame Curie noticed something which appeared to her very noteworthy. It was that pitchblend, which is the crude ore from which uranium is extracted and which consists chiefly of uranium oxide, would produce an effect upon a photographic plate, or would discharge an electrified body, in about one fourth the time in which the same weight of a pure uranium salt would produce the same effect. She inferred, therefore, that the activity of pitchblend in emitting rays could not be due solely to the uranium contained in it: that, on the contrary, pitchblend must contain some hitherto unknown element which had the property of emitting Becquerel rays more powerfully than uranium itself. She therefore immediately set about the task of separating as carefully as possible the dozen or so of substances which are contained in pitchblend, such for example, as uranium, barium, lead, copper, arsenic, antimony, and so on, and after each separation, testing the two portions separated to find which part carried with it the activity, that is, the ability to affect a photographic plate or to discharge an electrically charged body. The methods employed were the ordinary ones used in qualitative chemical analysis. The search was a long and difficult one, but ended triumphantly in the separation from several tons of pitchblend of two or three grains of the new element which has now become one of the wonders of the world.

The successive steps in this discovery were as follows: Madame Curie found, first, that in this process of separation of the constituents of pitchblend, the reagent which separated the barium out of the solution also brought down in the barium precipitate a large part of the activity. The barium chloride precipitate obtained in this way had about sixty times the activity of pure uranium chloride. She next found that when alcohol was added to a solution of this barium chloride, the first precipitate which was thus formed was more active than that which came down later. By retaining only this first precipitate and discarding the rest, and again redissolving and repeating the process over and over again (this process is called fractional precipitation) she succeeded in obtaining a sample of barium chloride which was 4,000 times as active as uranium chloride. Further, since the weight of the barium chloride for a given weight of contained chlorine was greater in the ratio 140 to 137 than the weight of ordinary inactive barium chloride for the same weight of contained chlorine, she concluded that the apparent activity of the barium chloride could not be due to barium at all, but must be due to this unknown element which

was mixed with the barium in the precipitate. She therefore announced definitely the discovery of a new substance which she named radium.

There is a second process, which is now more commonly used than the above, for separating this active substance, that is, the radium, from the barium with which it is always found. It is called the process of fractional crystallization, and consists simply in retaining the first crystals which crystallize out from an active barium chloride solution and then redissolving these crystals and allowing some of them to crystallize out again, and so on. With each new crystallization the activity of the crystals per unit of weight increases. In this way the Curies have recently obtained samples of radium which are as much as 1,800,000 times as active as uranium, the activity being measured by comparing the rates at which equal weights of radium and uranium will discharge an electrified body.

Having followed in this way the processes by which radium was discovered as early as 1898, let us turn to some of the other results which followed close upon the discovery of the X-rays, and which it is necessary to understand something about before we can intelligently discuss the nature of the radiation from radium and other radio-active substances.

The Nature of Cathode Rays.

I have said that X-rays are emitted by an exhausted bulb in which an electrical discharge is passing, but the very existence of X-rays is found to depend upon another kind of rays which are also connected with the electrical discharge from an exhausted tube. These are called the *cathode rays* because they originate in the negative electrode or cathode, see Fig. 1, of a discharge tube when it is put into connection

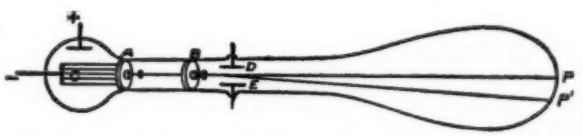

FIG. 1. ILLUSTRATING DEFLECTION OF CATHODE RAYS BY AN ELECTROSTATIC FIELD.

with an induction coil or static machine. These cathode rays were discovered long before X-rays. Fig. 1 will give some idea of how they manifest themselves. If *A* and *B* are two diaphragms, in the middle of which are two horizontal slits, then, when an induction coil is connected to the points marked + and — and set into operation, a small spot of greenish-yellow light will appear on the glass at *P*, just as though some sort of rays were emitted in straight lines from *C*, and, passing through the two openings *O*, fell upon the point *P*. There are a great many substances which, if placed anywhere in the line *OP* so that these cathode rays from *C* can strike upon them, will light up with a charac-

teristic glow. For example, if a screen coated with zinc sulphide is placed within a discharge tube in the manner shown in Fig. 2, the cathode rays which pass through the slit in the mica diaphragm just opposite the cathode, light it up brilliantly in the parts along which they graze, and thus trace a distinct outline of their path from one end of the tube to the other.

The nature of these rays was the subject of much dispute between the years 1880, when they first began to be studied, and 1898. Some thought them to be streams of minute negatively charged particles shot off with enormous velocities from the cathode *C*, while others maintained that they did not consist of particles at all, but were waves in the ether, just like light waves. The dispute was finally ended by two very conclusive experiments performed, the first by Perrin, a Frenchman, and the other by J. J. Thomson, professor of physics in Cambridge University, England. Perrin's experiment consisted in proving that under all circumstances a body which was placed along the path *OP*, so that the cathode rays could fall upon it, became charged with negative electricity, just as would be expected if the cathode rays consisted of negatively charged particles. J. J. Thomson's experiment consisted in showing that if a charge of positive electricity were placed upon the plate *E* (see Fig. 1), and a charge of negative electricity upon the plate *D*, the rays were deflected out of the line *OP* and into the path *OP'*. This, too, was to have been expected if the rays consist of negatively charged particles, for these particles would be repelled by the negative electricity upon *D* and attracted by the positive electricity upon *E*.

FIG. 2. SHOWING BEAM OF CATHODE RAYS.

FIG. 3. SHOWING DEFLECTION OF CATHODE RAYS BY A MAGNET.

There is a further property of the rays, which, although it had long been known, adds powerful support to the projected particle theory. It is that when a magnet is brought near the cathode beam in the manner shown in Fig. 3, the beam is deflected by it also, just as would be expected if it consisted of a stream of negatively charged particles. These three experiments settled the question in favor of the projected particle theory, so that physicists are now all agreed in regarding the cathode rays as streams of minute, negatively charged corpuscles shot off in straight lines from the surface of the negative electrode and in a direction at right angles to this surface.

Cathode Ray Particles Much Smaller than the Smallest Known Atom.

But the most remarkable result of experiments upon cathode rays is the conclusion that while they consist of rapidly moving particles, these particles are not ordinary atoms or molecules, but are instead bodies whose mass is only about one one-thousandth of the mass of the smallest atom known, namely, the atom of hydrogen. The calculation by which this conclusion is obtained is based upon a comparison of the amount of deflection which is imparted to the rays by a magnet of known strength, and the amount of deflection which is produced by electric charges of known size on *D* and *E*. It can also be based upon other experiments which will not here be described. Suffice it to say that more than a dozen well-known physicists have made the observations and the calculations upon which they are based, and that, although they have worked by as many as three different methods, the results are all in substantial agreement.

A New Theory as to the Constitution of Matter.

Furthermore, since experiments of the kind mentioned above always lead to the same value for the mass of the cathode ray particle, no matter what be the nature of the gas which is used in the bulb and no matter what be the nature of the metal constituting the cathode *C*, physicists have found it necessary to conclude that these minute particles are constituents of each and every one of the different metallic elements at least, and probably of all the other elements also. In view of these discoveries, the suggestion has been put forward by several of the greatest living physicists, that these cathode particles are themselves the primordial atoms out of which the 70 odd atoms known to ordinary chemistry are built up. According to this suggestion, the chief difference between the different atoms of chemistry would consist simply in differences in the number of the primordial atoms which enter into them. Thus the hydrogen atom would be composed of about a thousand of these minute corpuscles, or electrons, as they have been called, the oxygen atom of 16,000, the mercury atom of 200,000, and so on. It is necessary to assume, however, that these electrons are half plus and half minus, for otherwise we can not account for the uncharged condition of ordinary atoms. Since, however, no evidence has as yet appeared to show that positively charged electrons ever become detached from atoms, J. J. Thomson has brought forward the hypothesis that perhaps the positive charges constitute the nucleus of the atom, while the negative electrons are on the outside and are therefore more easily detachable. It is too early to assert this theory as correct; it is introduced here merely as a profoundly interesting speculation brought forward by men high in authority in the scientific world. It differs radically from most other speculations of the same general nature, in that it is based upon a certain amount of experi-

mental evidence. However, the experiments can not be said to have gone so far as to render its correctness even probable. This much, however, it is safe to say: the experiments upon cathode rays have *proved conclusively that under some circumstances particles do exist which are smaller than the ordinary atoms of chemistry.* It was the study of cathode rays, then, which first sounded the death-knell of the *indivisible* atom of our earlier chemistry and prepared the way for the discoveries, which were soon to follow, of subatomic transmutations which involve the liberation of stored-up energies, the very existence of which had never before been dreamed of .

The Nature of X-rays.

I have already said that cathode rays are very intimately connected with X-rays, for both are associated with the discharge of electricity in exhausted tubes. In fact, at the time of Röntgen's discovery, many physicists thought that the X-rays were nothing more nor less than cathode rays which had passed through the walls of the tube into the outside air. But Professor Röntgen demonstrated that the X-rays are wholly different from the cathode rays in these two important respects, namely: (1) they are not deflected in the slightest degree, either by a magnet or by bodies charged with static electricity; (2) they do not impart negative charges to objects upon which they fall. X-rays are therefore not cathode rays. They originate at the point at which the cathode rays strike against the walls of the tube, or against any object placed in their path inside the tube. In the ordinary X-ray tube a little plate of platinum is commonly placed in the middle of the tube, just opposite the cathode, for the purpose of receiving the stream of cathode rays. It thus becomes the source from which the X-rays proceed. This is about all that we know with certainty concerning X-rays. Most physicists, however, now believe them to be ethereal rather than material in their nature, that is, they believe them to be some sort of waves or pulses in the ether, not very dissimilar from light waves.

Radio-active Substances emit Cathode Rays.

We are now in a position to understand the experiments which were performed with radio-active substances, namely, uranium, thorium and radium, in order to discover the nature of their radiation. It was at first suspected that these rays were similar to X-rays, because, like them, they possessed the power of penetrating opaque objects and of affecting photographic plates. But as soon as the test which distinguished X-rays from cathode rays was applied, that is, as soon as a magnet was placed so that it could distort the photograph produced with the aid of Becquerel rays, in case these rays like cathode rays were deflected by it, it was found indeed that these photographs did indicate such deflection. It was further found that they could be bent out of

their course by electric charges just like the cathode rays, and, lastly, that, also like them, they imparted negative charges of electricity to objects upon which they fell. Further, when the mass of these particles was calculated by comparing the amount of deflection produced by a magnet with that produced by an electric charge, it proved to be, strangely enough, the same as that of the cathode ray particles. It seems certain, therefore, *that radio-active substances spontaneously emit rays which are identical in all respects with the cathode rays, i. e.,* which consist of minute negatively charged particles of about one one-thousandth the size of the hydrogen atom. The velocity with which these minute particles are shot off from the radio-active substances is found to be even more enormous than the velocity of the same particles in the cathode rays. The latter were found to move with a velocity which is sometimes as high as 20,000 miles per second. Now, the velocity with which light travels from the sun to the earth or from star to star is 186,000 miles per second. Hence, the cathode ray particles sometimes move with a tenth the velocity of light. But the velocity of the particles shot off from radio-active substances is still more surprising, for it sometimes reaches the stupendous figure of 175,000 miles per second, only a trifle less than that of light.

Other Radiations from Radio-active Substances.

But it was discovered in 1899 by Rutherford, of McGill University, Canada, that uranium, thorium and radium all emit other rays besides cathode rays, which are distinguishable from them, first by their very much smaller penetrating power and, second, by the fact that they are not ordinarily deviated either by a magnet or by an electrically charged body. He named these rays the *alpha* rays, while he designated the cathode rays emitted by radio-active substances as the *beta* rays. In order to separate the *alpha* from the *beta* rays, it was only necessary to lay over the radio-active substance, that is, the uranium, the thorium or the radium, a very thin sheet of aluminum; for example, a sheet .005 centimeter thick. This opposed almost no obstruction to the passage of the *beta* rays, but it cut off entirely the *alpha* rays. Another mark of difference between the two kinds of rays was that, while the *beta* rays were very much more effective than the *alpha* rays in penetrating opaque objects and in affecting a photographic plate, their influence in rendering a gas electrically conducting was very small in comparison with that of the *alpha* rays; so that if the thin sheet of aluminum were taken away, the gas above the radio-active substance became a hundred times as good a conductor as when the *alpha* rays were screened off.

There is also a third kind of ray given off by radio-active substances, which has been given the name of *gamma* rays. These are very much more penetrating even than the *beta* rays; but, so far, little

is known about their nature. Since, however, the energy carried by them is very insignificant as compared with that in the *alpha* and *beta* rays, we can leave them entirely out of account in most of the computations which we make upon the energy of radiations of radio-active substances. It is now conjectured that the *gamma* rays are ethereal pulses like the X-rays.

The Nature of the Alpha Rays.

It was at first conjectured that possibly the *alpha* rays might be X-rays, since, like them, they are not deflected by a magnet, and since, also like them, they are very effective in rendering a gas electrically conducting. But only last year Professor Rutherford contrived a very ingenious experiment by which he showed conclusively that the *alpha* rays are deflected very slightly by a magnet if the magnet is sufficiently powerful. He also succeeded in showing that they are deflected by a very strong electrical field. But in both of these cases the direction of the deflection is opposite to that obtained under the same conditions with *beta* rays. These results of Professor Rutherford's are of the utmost importance, and they have been recently confirmed both by Becquerel in Paris, and by a German physicist by the name of Des Coudres. The only possible interpretation which can be put upon them is that the *alpha* rays also consist of particles of matter shot off from the radio-active substances, but that, while the *beta* ray particles carry charges of *negative* electricity, the *alpha* ray particles carry charges of *positive* electricity.

Further, when from the amounts of the deflections produced by the magnet and by the electric charge, the size and velocity of the *alpha* particles are calculated, the results are again most interesting. For these particles are found to have a mass not one one-thousandth that of the hydrogen atom, like the cathode rays, but approximately twice as great as that of the hydrogen atom, or about the size of the atom of helium. (The atomic weight of helium is 4.) They are therefore about 2,000 times as heavy as the cathode ray particles. This explains why they do not pass through ordinary matter as readily as do the smaller *beta* particles. But despite this comparatively great mass, their velocity is found to be as much as 20,000 miles per second, more than a tenth that of the smaller particles. It will be seen, therefore, that the energy of the blows which they strike against the bodies upon which they fall is much greater than that of the *beta* particles. This explains why they knock the gas to pieces, or dissociate it and thus render it conducting, so much more energetically than do the *beta* particles.

The Crookes Spinthariscope.

We have attempted to follow, thus far, the evidence upon which we base the conclusion that the radiations from radioactive substances con-

sist, largely at least, of projected particles of matter expelled with enormous velocities from the active substance. But no amount of reasoning of the sort thus far given will be found half as convincing to the ordinary mind as the sight of a bit of radium at work. Radium itself, in the dark, glows with a light which resembles that of a glow-worm, and when placed near certain substances like willemite (zinc silicate) or zinc sulphide, it causes them to light up with a glow which is more or less brilliant according to the amount of the radium at hand. Last spring Sir William Crookes first exhibited the following most beautiful and wonderful experiment at the soirée of the Royal Society in London. A small bit of radium is placed about a millimeter above a zinc sulphide screen, and the latter is then viewed through a microscope of from ten to twenty diameters magnification. The continuous soft glow of the screen, which is all that one sees with the naked eye, is resolved by the microscope into a thousand tiny flashes of light. It is as though one were viewing a swamp full of fire flies, or, better still, a sky full of shooting stars. The appearance is as though the screen were being fiercely bombarded by an incessant rain of projectiles, each impact being marked by a flash of light, just as sparks fly off from an iron when it is struck with a hammer. Becquerel has recently brought forward evidence to show that the spark is due to a cleavage produced in the zinc sulphide crystal by the impact of the *alpha* particles. This explains why the effect is not observable with all kinds of screens.

The Continuous Emission of Light and Heat by Radio-active Substances.

After learning that the radio-active substances uranium, thorium and radium are, for some reason or other, continuously projecting with enormous velocities two kinds of particles, the *alpha* and the *beta* particles, one is not surprised to find that these substances maintain a temperature above the temperature of the surrounding atmosphere. This has been proved experimentally only for radium, which was found last year by M. Curie and M. Laborde to remain permanently at a temperature between one and two degrees centigrade above that of its surroundings, and to give out for each gram of weight enough heat per hour to raise a hundred grams of water through one degree. Since radium radiates more than a million times more actively than either of the other substances, it is not likely that any one will ever be able to show experimentally that uranium and thorium also maintain a temperature above that of their surroundings. Nevertheless, the same causes which operate to hold up the temperature of radium, operate also to hold up the temperature of both the other radio-active substances, the only difference being one of degree. Hence it is probable that all radio-active substances are continuously emitting, in a greater or less degree, heat energy. This is not surprising in view of the

conclusion that such substances are continually projecting particles with enormous velocities, for if these particles are projected from all the molecules of the active substance, it would be expected that the temperature of the mass of the substance would rise under this unceasing internal bombardment. But whence comes this energy which is represented in the projected particles, and of which this heat and light are the ultimate manifestation?

Radio-activity a Manifestation of Subatomic Energy.

The answer to this last question has not yet been fully given. This much, however, can be said, that, thanks to the splendid work of Rutherford and Soddy, of McGill University, of Sir William Crookes, of the Curies and Becquerel in Paris, and of one or two German physicists, a fairly satisfactory answer is at least in sight. Whatever be the cause of this ceaseless emission of particles by radio-active substances, it is certain that it is not due to any ordinary chemical reactions, such as those with which we have heretofore been familiar; for Madame Curie showed, when she originally discovered the activity of thorium, that the activity of all the active substances is proportional simply to the amount of the active element present and has nothing whatever to do with the nature of the chemical compound in which that element is found. Thus, thorium may be changed from a nitrate to a chloride, or from a chloride to a sulphide, or it may undergo any sort of a chemical change, without any change whatever being noticeable in its activity. Furthermore, radio-activity has been found to be absolutely independent of all changes in physical as well as chemical condition. A radio-active substance may be subjected to the lowest temperatures known, or to the highest temperature obtainable, without showing in either case any alteration whatever in the amount of its activity. Radio-activity seems therefore to be as unalterable a property of the atom of the radio-active substances as is weight itself. It is certainly something which is entirely beyond the range of ordinary molecular forces. This is strong evidence in favor of the view that radio-active change, *i. e.*, the change, whatever it be, which is responsible for the expulsion of the *alpha* and *beta* particles, involves a change in the nature of the atom itself. This is the first time in the history of science that any *subatomic* store of energy has been tapped by man, although, as stated above, the possibility of breaking up the atom was first proved by the study of cathode rays.

The Production of Uranium X.

The view that radio-activity consists in some change going on in the nature of the atom has received powerful support from a series of discoveries which were started in 1900 by an experiment performed by Sir William Crookes. He found that if uranium nitrate were precipitated by ammonium carbonate and then enough of the ammonium

carbonate added to redissolve the uranium nitrate, there remained behind an undissolved precipitate which contained a large part of the original activity which had been possessed by the uranium nitrate. He called this undissolved precipitate (or better, the portion of it which was responsible for the activity, for when chemically tested, it showed nothing but iron, aluminum and other impurities) uranium X. But he soon afterward discovered that the uranium nitrate, which had partially lost its activity through the separation from it of this unknown substance, uranium X, in the course of a few months had regained completely its original activity, while the uranium X had lost its power to radiate.

A little more than a year ago Rutherford tried the same experiment with thorium and found quite similar results. But more important still, he found that in both cases the rate of loss of activity of the separated substance, that is, of the uranium X or the thorium X, was equal to the rate of recovery of the uranium or the thorium from which the new substance had been extracted. To state this result in a slightly different way, he found that if all the uranium X were removed from a sample of uranium by this process, so that further precipitation by ammonium carbonate would bring down no more uranium X, and if the uranium were then allowed to stand till it had recovered one half of the lost activity, and if then the uranium X was again removed, the amount of this uranium X which could be obtained was now just one half as much as the amount obtained at first. If the uranium had regained three fourths of its original activity, just three fourths as much uranium X could be obtained from it as at first. This result seems capable of but one possible interpretation, namely, this: the uranium is continually producing, by some change which goes on within itself, some radio-active substance uranium X, which, however, is formed in such minute quantities that it can be detected and measured only by means of its radio-activity. Further, this uranium X itself is unstable, for it undergoes a change by which it loses its activity. Rutherford further found that in this separation of uranium X from uranium the part of the activity which was left behind in the uranium consisted entirely of the *alpha* type of radiation, while the part which was separated out in the uranium X consisted wholly of the *beta* type. This seems to show that the first step in the process of radio-active change consists in the expulsion from the uranium atom of the big *alpha* particles, while the *beta* particles are expelled only from some product which is formed by the disintegration of the uranium atom.

In all these particulars Rutherford found that thorium and uranium acted essentially alike, the chief difference being that while the uranium X loses one half of its activity in about twenty-two days, it requires but four days for the activity of the thorium X to decay to half its initial value.

The Emanation from Radium.

The examination of radium revealed a behavior exactly similar to that of uranium, for it too was found to be continually producing a radio-active substance which, when separated from the radium, slowly lost its activity, while the radium from which it was separated slowly regained its original radiating power. In the case of radium this new substance, unlike the uranium X and the thorium X, could be distinguished by other physical properties besides its activity. Thus Rutherford found it to be of the nature of a gas. It could be separated from radium by heating the latter, or by dissolving it in water. The radium which had been so treated lost for the time being all but one fourth of its original radiating power, the other three fourths being found in the gas, or emanation, as Rutherford called it. This gas could be carried by means of air currents through long tubes to considerable distances from the radium itself, its path through the tubes being easily traced by the fluorescence which it imparted to the glass walls of the tubes. It could be set away in bottles and the change in its activity watched from day to day. In this way it was found to lose about half its activity in a period of four days, while in the same period the radium from which it had been separated regained one half of its lost radiating power. By passing this gas or emanation through a tube immersed in liquid air, Rutherford found that it condensed at about —150° C. Ramsay has recently found that it appears to have a characteristic spectrum, as have all the elements. This gas, therefore, seems to be a substance of very definite physical qualities which is produced by the disintegration of the atom of radium in just the same way as the uranium X and thorium X are produced by the disintegration of the atoms of uranium and thorium. But this gas, like the uranium X and the thorium X, has but a transitory existence, for the fact that it gradually loses its activity shows that it passes on into something else.

Induced Radio-activity.

Nor did physicists have long to look in order to discover this substance into which the emanation from radium is transformed. The Curies found as early as 1899 that when this gas comes into contact with a solid object, the object becomes coated with a film of radio-active matter which can be dissolved with hydrochloric or sulphuric acid, and which is left in the dish when the acid is evaporated. Or which may be rubbed off with leather and found, by means of the property of activity which it possesses, in the ash of the leather after the leather has been burned. This radio-active matter is so infinitesimal in amount that in no case is it detected in any other way than by its radio-activity. It might, at first, look as though it were nothing but the active gas itself condensed on the surface of the solid object, but since the rate at which it loses its activity is altogether different

from the rate at which the activity of the emanation decays; and, more important still, since it is found to emit both *alpha* and *beta* rays while the emanation emits only *alpha* rays, it seems necessary to conclude that this film of active matter is a product of the emanation rather than the emanation itself. In fact it appears to bear in all respects the same relation to the emanation which the emanation does to radium. That is, *it is the result of the disintegration of the atom of the emanation, just as the emanation is the result of the disintegration of the atom of radium.*

In the case of thorium this continuous change from one radio-active substance into another has been followed with certainty through as many as four different stages, thus; first, thorium produces thorium X; second, thorium X produces an active gas or emanation which is very like the radium emanation; third, the thorium emanation gives rise to a radio-active substance which is responsible for the induced radio-activity which is observable whenever the emanation comes in contact with a solid object; fourth, this induced radio-active matter due to the thorium emanation gradually loses its radiating power, and hence must undergo at least one further change into some other substance.

The Disintegration of the Atom of Radio-active Substances.

We have endeavored to follow step by step the discoveries which have led up to our present knowledge of the nature of radio-activity. These discoveries have seemed to prove conclusively that the atoms of radio-active substances are slowly undergoing a process of disintegration, this disintegration being indicated, first by the fact that there is a continuous projection from them of particles of matter, the *alpha* and *beta* rays; and second, by the fact that we are able to detect the presence of new and unstable types of matter accompanying the phenomena of radio-activity. Just why these atoms are disintegrating and just how these new types of matter are formed must of course be largely a matter of speculation. Nevertheless, discovery has gone far enough to enable us to form a reasonably plausible hypothesis as to the probable mechanism of radio-active change. In presenting this hypothesis the first remarkable fact to be noted is that the three permanently radio-active substances thus far discovered, the only ones which can with certainty be classed as elements, namely uranium, thorium and radium,* are the substances whose atoms are the three heaviest

* There are two other substances which must perhaps be added to this list, viz., polonium and actinium. But neither of these has as yet been found to show a distinct spectrum or to show any of the other characteristics of elements; furthermore, the activity of one of them and possibly of both of them slowly decays. Hence it is possible that they, like uranium X and thorium X and the radium emanation, are only stages in the disintegration of radio-active elements. The present indications, however, seem to be that actinium is, like radium, a new and very powerful radio-active element.

atoms known. Thus the atomic weight of uranium is 240, that of thorium 232, that of radium 225 or, according to a recent spectroscopic test, by Runge, 256. There is no other property in which these three substances are at all alike. In their chemical characteristics they are extremely different. Now, according to our modern mechanical theory of heat, the atoms of all substances are in extremely rapid rotation. It appears, therefore, that these rapidly rotating systems of heavy atoms, such as characterize radio-active substances, not infrequently become unstable and project off a part of their mass. These particles which are first projected were found to be the *alpha* particles, and this process of projecting the *alpha* particles is the first stage of radio-activity. The mass which is left behind, namely, the uranium X, the thorium X, or the emanation, according as the original atom was uranium, thorium or radium, is itself unstable, and projects still other particles. The remainder, at least in the case of thorium and radium, is still unstable, and another particle is projected. Thus we were able to follow the disintegration of the atoms through at least four (according to Rutherford, five) successive stages. How many more stages there may be no one can tell, but as soon as the stable condition is reached and no more particles are projected the product is of course no longer radio-active, and its presence can no longer be detected by the delicate test of radio-activity. It is then only after it has accumulated in sufficient quantity to be capable of detection by the ordinary methods, namely, by spectroscopic or chemical analysis, that it could be expected to be found.

The Birth of Helium.

More than two years ago Rutherford, with this picture of the mechanism of radio-activity in mind, made a prediction which has recently been most remarkably verified. The history of science scarcely affords a more striking instance of the fulfilment of scientific prophecy. Since 'helium' (the element which was first discovered in the sun, by means of a line in the solar spectrum which did not agree with the lines of any of our known elements, and which was discovered on the earth only a few years ago by Lord Rayleigh and Professor Ramsay) is found in nature only in connection with radio-active minerals, *i. e.*, in connection with those minerals which contain uranium, thorium or radium, Rutherford predicted that helium would one day be found to be one of the ultimate products of the disintegration of the radio-active elements. A year later, it may be remembered, Rutherford himself found that the *alpha* particle, which is certainly one of the products of radio-active change, had about the same mass as the helium atom. This pointed still more strongly to the confirmation of his original prophesy. Last July Professor Ramsay and Mr. Soddy actually saw the spectrum of helium grow out of the emanation of radium. They collected the emanation from fifty milligrams of radium

bromide and, examining it in the spectroscope, found that it was characterized by a wholly new spectrum, probably the characteristic spectrum of the emanation. But after watching this spectrum for three days they saw the characteristic lines of helium beginning to appear. This seemed to prove with certainty that helium was being continually formed by the disintegration of radium.

The Life of Radium.

It appears, therefore, that all the three heaviest atoms known are slowly disintegrating into simpler atoms. The process is, however, extremely slow. Despite the incessant projection of particles from radium, so strikingly shown by the Crookes spinthariscope, no one has as yet been able to detect with certainty any loss whatever in its weight, nor any diminution in its activity. Yet we may be certain that in fact it is both losing weight and diminishing in activity; for otherwise the principle of the conservation of energy, the corner-stone of modern science, would be violated. From a knowledge of the amount of heat energy given off by radium per hour, viz., 100 calories, and a knowledge of energy represented by each projected particle (this knowledge we possess, since we know the mass and velocity of the *alpha* particles, the energy contained in the *beta* particles being wholly negligible in comparison), we can easily estimate certain limits within which we may expect all the radium now in existence to pass out of existence as radium. In the first place we obtain the number of *alpha* particles projected per second from one gram weight of radium atoms by dividing the 100 gram-calories by the kinetic energy of each *alpha* particle. The result of this calculation is 200,000,000,000 ($=2\times10^{11}$). Now there are 3×10^{21} atoms of radium in a gram of radium chloride. Hence if each atom of radium which becomes unstable threw off but one *alpha* particle, then the fractional part of any given number of radium atoms which become unstable per second would be simply 2×10^{11} divided by 3×10^{21}. This amounts to but one in fifteen thousand million. On the other hand, if each atom of radium which becomes unstable produces the maximum possible number of *alpha* particles, viz., 225/2, 225 being the atomic weight of radium and two the atomic weight of the *alpha* particles, then only one atom in sixteen hundred thousand million would become unstable per second. These two numbers represent then respectively the maximum and minimum possible rates at which the atoms of radium are becoming unstable. At the first rate radium would lose about one one-hundredth of its activity in five years, ninety-nine one-hundredths in 2,200 years and in 9,000 years it would possess no more than one hundred-millionth part of its present activity, *i. e.*, it would no longer be measurably active. Since we have brought forward good evidence in the foregoing para-

graphs that each atom of radium which becomes unstable throws off at least as many as four alpha particles before it again reaches a condition of stability, it is probable that the above lowest possible limit to the life of radium, viz., 9,000 years, should be replaced by 36,000. At the second or minimum rate radium would lose one-hundredth of its activity in about 500 years and in 900,000 years would be no longer measurably active. It appears then that within a period of a million years at most all the radium now in existence will have ceased to be radio-active, *i. e.*, will have ceased to be radium. The life of uranium and thorium would be from one to two million times as much, since they are radiating only about a millionth as actively.

The Transmutation of the Elements.

The discoveries which we have attempted to describe in the preceding pages have seemed to lead to the startling conclusion that in the case of certain elements at least, the dreams of the ancient alchemists are true, for the radio-active elements all appear to be slowly but spontaneously transmuting themselves into other elements. The present indications seem to be that this transmutation which is going on in nature is a change from the heavier atoms to the lighter ones. Whether any other heavy atoms besides those of uranium, thorium and radium are thus slowly disintegrating, we can not say, but probably actinium must be added to the list. If any of the other known heavy elements, like gold, lead, barium, bismuth, mercury, are undergoing such a change, it is too slow to be detected even by the delicate test of radio-activity. But it is interesting to note that the only changes of this kind which have thus far been discovered to be going on among the atoms are in some respects similar to the changes which are going on in the organic world among the molecules. By the ordinary process of decay, all organic compounds, which represent very complex molecular structures, are continually disintegrating into simpler ones, and in so doing are setting free the energy which was put into them when the processes of life built them up into complex forms. Similarly, the studies of the last eight years upon radiation seem to indicate that in the atomic world also, at least *some* of the heaviest and most complex atomic structures are tending to disintegrate into simpler atoms. The analogy suggests the profoundly interesting question, as to whether or not there is any natural process which does, among the atoms, what the life process does among the molecules, *i. e.*, which takes the simpler forms and builds them up again into more complex ones. It would be rash to attempt to give any positive answer to such a query, yet the fact that radium now exists on the earth, taken in connection with the fact that the life of radium is short in comparison with the ages in which the earth has been in existence, certainly seems to point to an affirmative answer. The only other alternative is to assume that

radium is itself a product of the disintegration of some heavier element which has been undergoing this process of decay since the world began.

Subatomic Energies.

The energy which would be required to produce such changes from the simpler to the heavier atoms, and the equivalent energies which are set free when the heavier atoms disintegrate into simpler ones, are enormously greater than those involved in the changes which take place in the constitution of molecules in the ordinary chemical transformations with which we have thus far been familiar. The disintegration of a gram of uranium, or thorium, or radium, sets free at least a million times as much energy as that which is represented in any known chemical change taking place within a gram weight of any known compound substance. The experiments of the last eight years have then marked a remarkable advance in science in that they have proved the existence of an immense store of subatomic energy. It seems highly improbable, however, that this energy can ever be utilized on the earth to serve man's economic needs, for thus far we know of but three substances which are disengaging it and these are changing so slowly that the rate of evolution of energy is almost infinitesimal. Radium may possibly prove to be of some practical value in the cure of disease, although it is too early yet to assert even this with certainty. But even if no practical application of these discoveries should be found, radio-activity will nevertheless have served one of the most useful of all ends, namely, that of enlarging man's knowledge of the ways of nature and of deepening his insight into the constitution of matter.

EVOLUTION OF THE HUMAN FORM.

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THAT men, or thinking beings akin to man, exist only on that minute fragment of the universe we call the earth is a conception so highly improbable, in view of the vast multitude of planets which we may logically conceive to exist, that it seems as if no reasoning being could entertain it. It is true, indeed, that in our own solar system perhaps only two or three of the planets, perhaps only the earth, are in a condition suitable for human habitation, and that the earth has been so for a comparatively brief period. It may well be, therefore, that only a very small percentage of the planets of space are in a similar condition. But in view of the vast multitude of planets that presumably exist, the number of those that possess reasoning beings is probably great. If we deal with this question from the point of view of actual evidence, the fact that the only planet whose conditions we know is inhabited by man is a strong argument in favor of his wide-spread existence. On the other hand, the fact that man's existence upon the earth is dependent upon a certain limited range of temperature, of brief duration in the earth's total history, is an argument on the opposite side, and goes far to narrow the possible domain of life in the universe. Yet if we extend our view to embrace the past and the future as well as the present, we can not avoid the conclusion that the realm of life and thought in the universe is an immense one.

To this question of the existence of thinking beings appertains another, that of their form or physical character. Are we to suppose that these beings, wherever placed, resemble man, or that each planet develops a type of its own, and that, if we could bring together a collection of the *men* of different sections of the universe, we should have a diversified museum of animal forms, with but one characteristic in common, that of the faculty of abstract thought? This is the conception usually entertained by those who have indulged in speculation or fiction concerning the inhabitants of Venus, Mars and other planets of our system. Yet it is one that may be questioned. A study of the development of life upon the earth seems to lead to the opposite conclusion, and yields warrant for the theory that thinking beings, wherever they may dwell, resemble man in body as well as in mind In other words, we have reason to conclude that, if we were capable of

traversing the universe, we should find beings akin to ourselves in many a remote corner of space.

On the earth, indeed, life exists under conditions which may be widely departed from in many other planets. Here the extreme range of favoring temperature is that between the freezing and the boiling points of water, the practical range being much smaller. Special conditions of surface material and formation, atmosphere, chemical action, etc., are also necessary. It is far from certain that the same conditions are necessary everywhere. Life may perhaps flourish on other planets under quite different conditions of temperature, gravitation and chemical action. It is true that, if all the spheres of space are made up of essentially the same chemical elements, as spectrum analysis seems to show, the range of life conditions can not greatly vary. Yet if the more abundant and active elements in any sphere differ from those of the earth, the consequent life conditions might vary accordingly and life exist under relations of temperature and chemical action unknown to us. The one thing essential, in every case, is an environment favoring organic chemism.

All this, however, is a side issue. It has no necessary bearing upon the question of animal form. If human beings could exist on some planets at 1000° instead of 100° F., and be made up of a protoplasm of quite different chemical composition, their forms and modes of action might still be closely the same. For the external forms of animals are due to physical, not to chemical, conditions. They are mainly results of the struggle for existence, and the effort to gain the most effective formation for the incessant battle of life. This must go on wherever life appears and develops, wherever the temperature or the active chemical elements may be. Much the same may be said of internal development. It seems to us that in any advanced stage of life the energy of animal motion must be a consequence of chemical change, due to something equivalent to oxidation of the tissues. There must also be an efficient agency for the supply of fresh nutriment to the wasting tissues, nerves for sensation and muscles for action, excretive and reproductive organs, etc., in short, organic conditions analogous to those which exist in our own bodies.

In truth, the minuteness of the earth as a planet, and the seeming insignificance of its life story as compared with that of all spheres and all periods, are apt to give us a false impression of the real significance of the development of life upon our place of abode. Though the process of organic evolution here may seem to us a minor one, a review of its history will serve to show that it has been a major one. And its final outcome in man can hardly be looked upon as a fortuitous result, but seems rather the inevitable consequence of an innumerable series of experimental variations. The life period upon the earth has

been a very extended one, stretching through many millions of years, and living matter has passed through an extraordinary diversity of forms, from microscopic specks of primeval jelly to the highly organized form of man. Of any planet upon which thinking beings have appeared, doubtless much the same may be said. The beginning must have been at the same low level; the gradations must have been similar in general character; the ultimate may perhaps have been widely different, though there are what seem good reasons for believing that it was closely accordant.

The final result of organic evolution depends largely upon external relations, the environment; largely upon the relations of organic matter to the chemical conditions of this environment. In certain particulars this has remained persistent throughout. The presence of water and air and the active oxidation of organic substance have been essential conditions of plant and animal existence through all the earth's life era. In other particulars the environment has varied immensely. At first physical only, it soon became in large measure vital. Organic beings, at first struggling for existence against adverse inorganic conditions, soon had to add to this a struggle against one another. As life grew more complex and diversified, so did the vital environment. The hurtful or helpful effects of heat and cold, storm and calm, poisonous and nutritious food, and other inorganic agencies, became of minor importance as agents in evolution in comparison with the intense competition for the food supply between living forms. The development of the carnivorous appetite in animals, with the subsequent necessity of methods of escape or defense in food forms, has been the most prominent selective agency in organic evolution, and the one to which we mainly owe the great diversity of advanced forms now existing. The struggle has been not alone between higher assailants and lower fugitives. It has also taken the form of the assault of lower upon higher forms. And it is of great interest to find that man, the highest of all, finds his most dangerous organic foes in the disease-producing microbes, among the lowest forms of life.

Life, then, in its progress upward, has moved in a somewhat narrow lane, whose borders it could not cross without encountering death. And in dealing with earthly evolution, we are in great measure dealing with evolution everywhere; since, whatever the organic conditions and the inorganic environment, the vital struggle for existence must have been much the same in all life-containing spheres. Nature may be held to have tried a great experiment upon the earth, carried on through a vast stretch of time, as if with intent to discover what ultimate result would arise from this long-continued action of inorganic and organic forces upon living forms.

This experiment has not lacked a sufficiency of material. During

unknown millions of years it has had to do with forms innumerable, a great battle going on in which myriads of unlike combatants were pitted against one another, each species being produced in such multitudes as to give it the fullest opportunity to sustain itself if capable. At every stage of the conflict the best adapted forms crowded down or annihilated their inferior competitors; themselves to be similarly dealt with when some new and superior combatant appeared. One needs only to look down the long record of paleontology, and consider that this represents only unit survivors of untold myriads, to recognize that nature has dealt with a superabundance of material, and to conceive that the final result may have been inevitable rather than fortuitous.

If we attempt to review the course of organic evolution upon the earth, we find ourselves confronted with so many types of life, so great a diversity of forms, such varied methods of motion and degrees of activity, that it is quite out of the question to deal with the subject adequately in a brief space. We can simply glance at it here, as an attempt to follow the whole line of progress would lead us too far afield.

Taking organic evolution as a process of colloid cell development—in distinction to the inorganic crystal development—we meet with a probably very long period of pristine evolution in which a single cell composed the whole organism. From this period examples indicating perhaps nearly the whole process of evolution still survive. The possibilities of progress in this direction were apparently very fully tried before organisms composed of a number of cells appeared. But when these came they quickly showed their superiority to the single-celled type alike in size and in complexity of organization.

From the basic generalized condition of living substance two great organic kingdoms arose, the fixed and the moving forms, plants and animals, the one living upon inorganic, the other upon organic material. Between these two inevitable resultants of the nutrient conditions the question of comparative rank is self-evident, the animal takes precedence of the plant. But the development of the latter was only in a minor degree due to inorganic influences. In water, where the animal assault on plants is not great nor varied, their evolution has been small. On land, where it has been severe and diversified, plant evolution has been large. But in no instance has it advanced from the purely physical to the conscious stage.

It is to the metazoa that we must go for the higher stages of evolution. Of the varied phases of this type of life, we can refer only to those of general character. No matter upon what planet life may have originated, we can not well avoid the conclusion that it must have had the organic cell as its unit, and that everywhere in its upward progress the many-celled self-moving form, feeding upon organic nutriment,

must have been reached, as a stage superior to the minute single-celled animal, or the immobile plant, fed with inorganic nutriment.

If we may then accept it as inevitable that organic evolution everywhere, if sufficiently advanced, must have reached the stage of the metazoon animal, this may be taken as the necessary basis of higher progress in any life-bearing planet. In the metazoon we have a creature consuming organic food, which it is necessary to seek, and thus needing powers of self-motion, either of the body as a whole or of its members. And in any planet in which beings equivalent to man appeared the faculty of consciousness must have been equally necessary at an early stage, as a highly advantageous aid in the struggle for existence.

This type of life once attained, it formed a fertile field for the operation of the principle of natural selection. Upon the earth, and presumably everywhere, it developed into innumerable forms, each adapted to some passing or permanent condition of the environment. Assuming that the agencies of internal organic activity were everywhere much the same—including active chemical change, due to oxidation or something similar, vascular organs for the conveyance of nutriment to the wasting tissues, apparatus for sensation and motion, and the like—and that these led to the development of specialized organs equivalent to the lungs, the heart, the brain, etc., we shall confine ourselves here to the subject of variation in outward form and condition.

Even in this there are a multitude of relations to consider, and we can deal here only with those of general character. A main one is that of activity as contrasted with inactivity. Many of the new forms became sessile animals, their only active parts being tentacles or other organs of offense and defense. Others became free-moving animals. Of the two types the latter was evidently the best adapted to high development, both physical and mental, its free motion greatly diversifying its environment and bringing it into much more varied relations than could be enjoyed by the plant-like sessile forms. The more active the animal, the more diversified its powers of motion, the more acute and varied its organs of sense, the more alert its powers of consciousness, the higher seemingly would be its position in the ranks of life and the superior its opportunities for upward progress. And this rule must have prevailed not only on the earth, but throughout the universe.

This being the case, not alone the sessile, but the sluggish, forms were at a disadvantage as compared with the active. Anything, then, likely to prevent rapidity and diversity of motion must have acted as a check to progress. Activity is essential to the most effective offensive powers, and upon these the higher stages of development depend;

but various types of animals became defensive rather than offensive in habit. These include the armored classes, of which the mollusks are the most marked example. To these may be added the forms that seek concealment, either by burrowing or otherwise. These creatures are necessarily sluggish, either from the weight of their armor or their lurking habits. They live upon inactive food, their environment is limited, their contact with nature narrow, their powers of sensation and consciousness little developed. The conditions of their life definitely take them out of the line of the higher progress, in which they can not compete with the more active forms.

In considering then the classes of animals adapted to advanced development, it seems necessary to confine ourselves to the free-moving, agile forms. And among the inhabitants of the ocean—in which life had its origin and its lower stages of development—these are not to be sought among the crawling and burrowing, but among the swimming species. With these the highest activity is dependent upon the most suitable formation of body and the most capable organs of motion.

If we may pursue our fable of nature's experiment in evolution, it can be said that very numerous trials in form were made. There seem possible to colloid substance only two general types of form, the circular or radial and the elongated. Both these were produced in numerous varieties, the circular type embracing two large classes of animals, the cœlenterata and the echinodermata, all of them sluggish, many of them sessile, their general shape and radiated limbs being very ill adapted to active motion. In this respect they were at a great disadvantage as compared with the bilateral, elongated type.

We thus seem to find the experiment of organic evolution, after millions of years of incessant effort, reaching the type which in its simpler stages is popularly designated as the worm, as the form best adapted for advanced evolution. The pristine worm was not in itself a promising creature. Its organs of motion were inefficient and its movements sluggish. Probably several worm-like types appeared, simply organized elongated animals of varied formation, to which we owe, in their final development, the three classes of animals known as the mollusca, the arthropoda, and the vertebrata. This development of an elongated, bilateral animal would seem to have been an inevitable stage in the evolution of animal life, sure to appear in any planet where life had sufficiently progressed, and capable of unfolding into a number of different types. In addition to the great types named, several of minor importance appeared upon the earth, and different ones may well have arisen elsewhere.

Yet if we seek for the highest class of form likely to arise from the worm-like unit, our field of search is restricted. If activity and flexibility of body are advantageous, we must seek these in the swimming rather

than in the crawling forms; in the naked rather than in the armored; in those of simple rather than in those of multiple organization—like the arthropods; in those with lateral rather than in those with oral limbs—like the mollusks; and finally in those with the smallest available number and most efficient character of limbs and other organs. This leads us to the vertebrates for the highest type that appeared in the waters of the earth, as the outcome of forms almost numberless in variety. In this we have an oval-shaped elongated animal, its organs of motion much the most effective of the many that had appeared in the progress of life, its vital organs unified and simplified to the greatest extent possible, its skeleton internal instead of external, used solely as a support, in no sense as an armor.

If we consider the fish in its most primitive varieties, we certainly seem led to the conclusion that it is the form to which the evolution of life would lead in any planet, as the basis of the higher development. In *Amphioxus,* for instance, we find the elongated bilateral animal simplified to an extraordinary degree; without external armor of any sort, with the simplest vital organs, with only the beginning of an internal skeleton, and with merely the suspicion of a fin, virtually a flattening of the skin. In this form we have the vertebrate reduced to its lowest terms, or the worm advanced to its highest. In the hag we find again a boneless and scaleless creature, with a sheath of cartilage to represent the backbone and with no organs of motion other than a fin-like flattening around the tail. Much the same may be said of the lamprey. From forms like these the fish seems to have developed, with all its subsequent variations.

The fish remains the highest form of water-developed life. It has made comparatively slight steps of progress during the immense interval since the paleozoic age. The limitations of its habitat seem to have checked the development of organic form at this stage. It can not be said that the evolution of life in the water has been in any sense restricted by deficiency of time or narrowness of variation. The variety of forms that have appeared is surprising when we consider the uniformity of conditions in the water, and are only to be accounted for as the result of a very active vital struggle. We find its simplest and least specialized higher result in *Amphioxus,* of which the ultimate result is the fish, beyond which, during millions of years, no progress has been made. And a full consideration of what has taken place on the earth strongly suggests that the oceanic evolution of life in any planet must have ended at some not dissimilar stage. Mentally it stands at a low level; and the whale, a mammal which has returned to the fish-form, is as low as the fish in mental powers.

Life in water was the basis of life on the land. It could not originate there *de novo,* land conditions being unadapted to the early life

stages. Land life was therefore handicapped by its origin. It had to start with what the ocean had to offer, and to begin with physical conditions which afterward could, at the best, only be modified. These conditions have left ineradicable traces even in man, the most removed of all from the original types. Of water animals only the elongated forms sent representatives to people the land—the worm, mollusk, arthropod and vertebrate. And of these, the latter two alone seemed well adapted to their new habitat, the arthropod developing into an extraordinary multitude of species, though its inferiority of organization removed it, at the start, from any competition with the vertebrate as a basis for the higher evolution. We find in the bee and the ant the ultimate development of the insect intellect, and the insect form is decidedly restricted by its characteristic condition.

Despite the immense variation that has taken place in land vertebrates, their marked departures from the fish type have not been numerous. One of the most important of these was the development of the fin into the limb, yielding the quadruped. Another was the replacement of the gill by the lung. But varieties of partially air-breathing and four-paddled fishes still exist, as if to serve us as object lessons in these stages of development.

Land animals were exposed to much more varied natural conditions than water animals and the struggle for existence between different forms was quite as acute. Yet, though a vast number of differing forms appeared, they were all built on the original lines of structure, the type of organization of the fish strictly limiting that of the land vertebrate. A development takes place, but it is on the lines already laid down. The internal organs vary and become more effective in action, the cold-blooded is succeeded by the warm-blooded, the egg-bearing by the young-bearing, etc. There is much change in external form. Animals became adapted to running, to flying, to swimming, to crawling, to burrowing. There are many variations in the feet and limbs, and in some cases these vanish, as in the serpent and the whale. Some animals are clothed in scales or bony armor, some in hair or feathers. But no new type appears, and though the mental powers increase, ages pass with little indication of the coming of any animal possessed of advanced powers of thought. Mentally the higher land vertebrate progresses far beyond its highest water kindred, but its powers of thought, after gaining a certain development, remain in great measure dormant, and there is nothing to indicate that the quadruped could ever progress in thought beyond a certain low level. If so on the earth, probably so everywhere: the influences acting on the quadruped do not seem calculated to produce any advanced thinking powers.

We have, in the foregoing pages, followed in its general features the evolution of animal life upon the earth. In view of the immense

period over which this evolution has extended, the extraordinary variety of forms which have appeared, and the strict limitations of the problem by natural influences, chemical, meteorological and vital, it is not easy to perceive how the final result could have deviated widely from that which we have before us. If the process were gone over again upon the earth, the great probability is that it would end once more in the mammalian quadruped. On other planets different chemical and physical conditions might affect the result, though the general principles of vital action could not greatly deviate and the evolution of the organs would doubtless pursue much the same course. As regards external form, the struggle for existence must operate in the same way and probably to the same effect.

Let us, for example, take the head of the quadruped, with its facility of motion, its apparatus for mastication, its sense organs, its nerve center. Can any one suggest an improvement upon the general arrangement of these organs, the ultimate outcome from a myriad of experimental efforts? The nasal openings stand above the mouth, in the best position to give warning of dangerous odors from food. The eyes are placed at the highest altitude and in the frontal position, the best location for their special duty. The ears are situated to catch sounds from the rear and the front, but preferably the latter. The brain is situated in the immediate vicinity of these organs of special sense, as if to favor quickness of sensation. All the organs of the head, indeed, seem remarkably well placed and adapted to their particular duty, and when we consider the varied positions which these organs have occupied in lower forms of life, we may justly look upon those in the quadruped as the final 'posts of vantage' resulting from a multitude of trials. Similar deductions might be made from other sections of the body, internal and external.

But we have not yet reached the evolution of a thinking being, an animal dependent much more upon its mental than upon its physical powers. In each advanced type of animal some mental progress was made; largest of all in the quadruped mammal; yet even in the latter it ended at a low stage. This is evident if we compare the quadruped with man, the former dependent very largely upon its physical, the latter mainly upon his mental powers. Evidently, in any planet, some step of progress beyond the quadruped was necessary for this result. On the earth this step was towards the form of man, the only true biped. May it not have been different in other planets, yielding human beings widely diverse in form and general bodily relations?

The answer to this query depends upon that special characteristic to which man—wherever found—owes his superiority. His physical difference from the lower animals is by no means great. It consists principally in an adoption of the upright attitude, a reduction of the

organs of locomotion from four to two and the development of a hand with grasping powers. But in this physical deviation lies the secret of the whole mental deviation. The species of animals below man are obliged to depend upon their personal organs, being incapable of availing themselves of natural objects. The elephant, with its grasping trunk, and the apes, with their partly freed hands, are nearly the sole exceptions to this rule. Man, on the contrary, by the freeing of his fore limbs from duty in locomotion and the grasping power of his hands, became able to add to his own powers those of nature, to employ weapons and tools fashioned from non-living matter, and thus to initiate a new cycle of evolution that was scarcely touched upon in the world below him.

The employment of tools and weapons separate from those provided by nature in the body is a condition demanding the active exercise of the mental powers, and at once gave man an incitement to the development of the mind which did not exist in the lower animals. We need not pursue this subject farther. The new process of evolution thus begun,—that of the exercise of the faculty of thought in making use of the powers of nature— it went on until it yielded man as he now exists, a being in whom the intellect controls not only his own bodily actions but largely all nature below him.

If now, we may justly conjecture that animals resembling our quadrupeds in general organization appeared on other planets, and if a thinking being analogous to man also appeared on any of these planets, it is very difficult to conceive how he could have arisen in any widely different way. It certainly seems as if the evolution of the higher intelligence in any planet must have depended upon some means of making use of the forces of nature, and the first step towards this, starting from the quadruped, would seem necessarily to be in the direction of the biped, with free arms and grasping hands.

There is thus considerable reason to believe that the beings which answer to man upon any of the planets of the universe must at least approach man somewhat closely in physical configuration. They may differ in minor details of organization, in many cases they may have escaped the special organic weaknesses of man, but it certainly seems as if a human traveler, if he could make a tour of the universe, would find beings whom he could hail as kindred upon a thousand spheres.

THE AREQUIPA STATION OF THE HARVARD OBSERVATORY.

By Professor SOLON I. BAILEY,
DIRECTOR OF THE AREQUIPA STATION.

THE same restless energy which impelled the American people to become a world-power has led their men of science to extend the range of their researches. The possibilities of a nation's influence are bounded only by the whole earth; and in a similar way the field of astronomy is limited only by the whole sky. At the latitude of Cambridge, Mass., an observer can never see more than three fourths of the sky. In order to observe the remaining fourth, which lies about the south pole of the heavens, he must seek some station below the equator. A complete study of all the stars in the sky is imperatively demanded for the solution of many of the great questions which the astronomy of the future must answer. Only by bringing such completeness into astronomical research will the construction of the universe and the true place of our solar system become known.

The Arequipa Station of the Harvard College Observatory owes its foundation to the far-sighted policy of its present director, Professor Edward C. Pickering. Under his direction, in 1889, the writer of this article visited South America in order to make the preliminary studies necessary to the selection of a station for the observation of the southern sky. The west coast of South America was chosen for this purpose, since it offered the possibility of great altitude, in addition to a dry climate and a clear atmosphere. The funds for this enterprise had been bequeathed for such a purpose by Uriah A. Boyden, a Boston engineer.

From the best information which could be obtained in the United States, it was thought that the valley of the River Rimac, near Lima, Peru, would furnish conditions favorable for the proposed station. The valley itself, however, did not offer a sufficiently free horizon, being shut in everywhere by mountains. There was a wide range for choice in regard to elevation. The hills near Lima are only a few hundred feet in height, while the great mountains forming the western Andes rise eighteen thousand feet above sea level. The primary conditions were an open horizon and a clear sky. To obtain a free horizon it was only necessary to climb one of the steep and barren summits near the valley; but to determine where the sky was clearest was a more difficult problem. At this latitude the western Cordillera extends

nearly parallel to the coast at a distance of perhaps sixty or seventy miles in an air line. The amount of cloudiness at different distances from the coast varies enormously. A different cloud system prevails on the coast from that in the mountains. The rainy season in the mountains is from November or December to March or April, more or less in different years. Toward the coast the rainfall grows less, while, in general, little or no rain falls within thirty or forty miles of the ocean. In Lima there is no rainy season, but there is an extremely cloudy season. This is due to the low cloud which is found more or less along the whole coast. This coast cloud is most prevalent from May to November. Throughout a large part of the year, however, the coast region of Peru, though almost rainless, is very cloudy. It seemed, therefore, that while the lofty clouds which cause the rainy season in the interior are gradually dissipated many miles from the coast, and the dense coast cloud never extends far away from the ocean, a situation chosen between these two, if such were possible, might, perhaps, escape both. With these ideas in mind a site was selected on an isolated summit, at a distance of about twenty-five miles from the coast, and at an elevation of six thousand five hundred feet.

The provisional station thus selected was at a distance of about eight miles from the village and hotel of Chosica, in the Rimac Valley, from which all supplies, of both food and water, were obtained. The residents of the hotel were our nearest neighbors, with the exception of occasional wandering herdsmen. In many ways it was an ideal location. It was named Mount Harvard, and became well known in Peru. The outlook was superb. To the east the ranges rose ever higher and higher to the Great Andes; to the west they fell away in numberless crests and wavy lines to the Pacific. Five miles away in a straight line a glimpse of green indicated the valley of the Rimac. The rest was hidden by mountains. In every direction nothing but barren mountains was to be seen. Where the buildings stood the soil was a hard sand, covered here and there with huge bowlders and with many varieties of cacti. To the north and south we looked down into gloomy ravines thousands of feet deep. To the east and west the slopes were more gradual, and there were charming little valleys needing only water to make them spots of beauty.

The buildings on Mount Harvard were portable structures, carried for the most part from the United States. They were made of a light framework of wood, covered with canvas and heavy paper. These houses and the instruments were conveyed from Chosica on muleback over a trail constructed for the purpose.

Life on Mount Harvard was somewhat lonely and monotonous, especially for Mrs. Bailey, who seldom enjoyed the society of any woman, except that of our amiable half-breed cook. Perhaps the most

unique feature was its situation between two clouds. Below us to the west was the coast cloud, which reached a varying distance inland according to the topography. Up the Rimac Valley it flowed like a great river; occasionally it filled not only the valley, but the barren ravines that branched from it north and south, rising till it covered even the ridges at our feet and, flowing around us, formed islands of Mount Harvard and the other more lofty points. The upper surface of this cloud was very sharply defined, but of wave-like form, so that its resemblance to water was at times so perfect that we could with difficulty persuade ourselves that far beneath its under surface all the varied activities of ordinary life were going on cheerfully. If from this view of 'clouds wrong side up' we turned our eyes upward, we at times saw another cloud system far above us; so that frequently we were between two clouds in a wide but shallow world, ourselves, perhaps, the sole inhabitants.

Fortunately for our work, the clouds above us appeared but seldom during the first months of our residence on Mount Harvard. During this time the extension of the Harvard photometry to the southern sky was begun. This is a determination of the brightness of all stars visible to the naked eye, a work begun by Professor Pickering in 1879. Photographic work was also carried on. The climatic conditions from April to September were excellent, but later clouds became troublesome. This condition of the sky growing worse as the cloudy season approached, it was decided to devote the following months to a meteorological study of different localities along the coast, and incidentally to extend the work of the meridian photometer in some region more free from clouds. Of the clearness and steadiness of the atmosphere in these different localities there was no certain knowledge, and the only way was to investigate it for ourselves. We left the Mount Harvard Station early in November in charge of a Peruvian assistant. During the next four months a personal examination was made by Dr. M. H. Bailey and myself of what appeared to be the most desirable localities along the coast, including Arequipa, the region about Lake Titicaca, both in Peru and in Bolivia, the Desert of Atacama, Valparaiso, Santiago and various other places in Chili. Perhaps no spot in all America offers a clearer sky than the Desert of Atacama. More than a month was passed at Pampa Central, near the center of this desert, and a study was made of the meteorological conditions, while the work of the meridian photometer was rapidly extended. There is a striking difference during the Peruvian cloudy season, between the cloudiness at Mount Harvard or at Arequipa, where the conditions are similar, and that on the Desert of Atacama. This is well shown in the following brief table, where *A* represents a perfectly clear sky during the whole night; *B*, a clear sky for a portion of the night; *C*, sky partially cloudy all night, and *D*, sky completely cloudy all night.

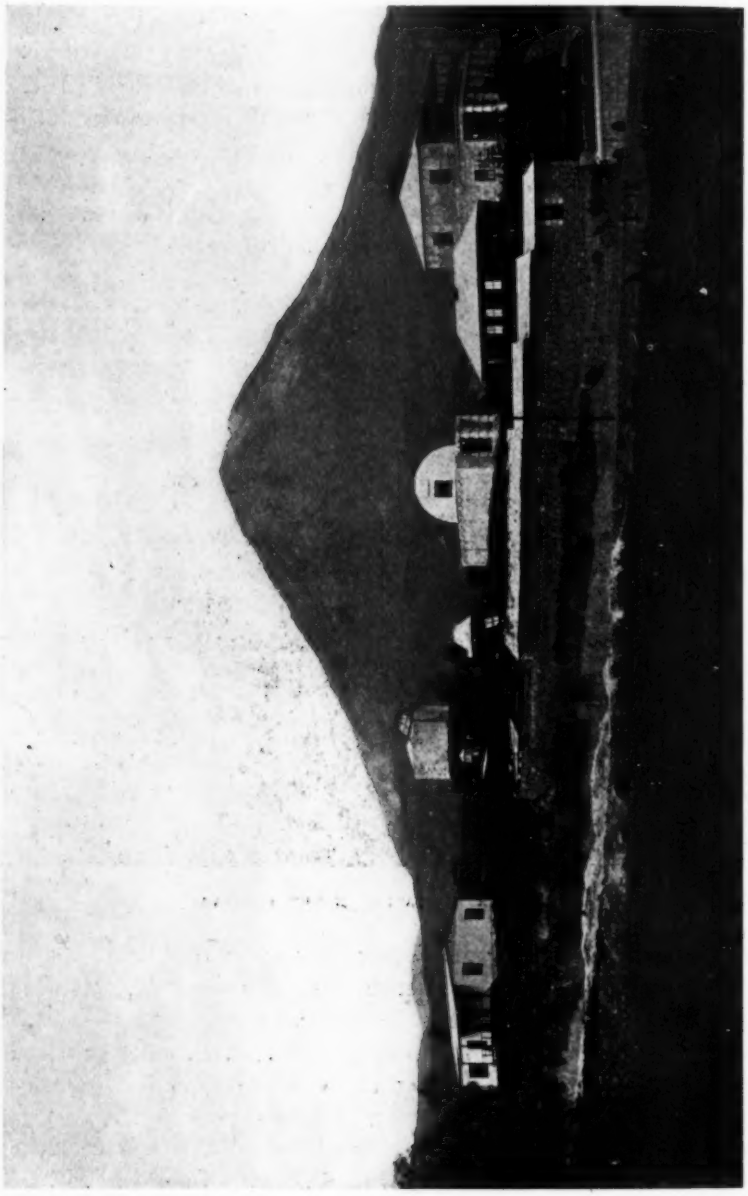
			A	B	C	D	Total.
1890.	January.	Pampa Central	21	7	0	1	29
"	"	Mount Harvard	0	2	2	27	31
"	February.	Pampa Central	12	12	1	3	28
"	"	Mount Harvard	0	0	0	28	28

A record of the cloudiness was kept not only at Mount Harvard, but at Arequipa and Pampa Central for some time after our residence in Chili. The cloudy season at Mount Harvard and Arequipa is in the southern summer, that of Pampa Central in the southern winter. By changing from one to the other of these localities one could keep in a region of clear sky nearly the whole time.

THE TEMPORARY STATION ON MOUNT HARVARD.

As a result of the investigations thus made the director selected Arequipa for the site of the permanent station, and the equipment on Mount Harvard was removed to that city in October, 1890. In January of the following year Professor W. H. Pickering arrived in Arequipa, bringing with him the thirteen-inch Boyden telescope and other smaller instruments. Under his direction a residence for the astronomer in charge and his family was erected, and two additional buildings were received from the United States. One of these was designed for a laboratory and the other for the use of the Boyden telescope. During his two years' residence in Arequipa, Professor Pickering, assisted by Mr. Douglass, made a large number of observations of Mars, and of the satellites of Jupiter and Saturn, as well as of the

lunar surface, all of which attracted wide attention. The steadiness of the atmosphere at Arequipa makes it an especially favorable spot



THE AREQUIPA STATION OF THE HARVARD OBSERVATORY.

for the use of higher powers, and for the study of faint and difficult planetary details. For double star work also the conditions are extremely good, and a large number of new and interesting double

stars have been discovered by Professor Pickering, Mr. H. C. Bailey and the other members of the observatory.

At the present time the equipment of the Arequipa Station of the observatory consists of the following instruments: the thirteen-inch Boyden telescope, an instrument so constructed that, by a change in the position of the lenses, it may be used either for visual or for photographic work; the twenty-four-inch Bruce photographic telescope, the most powerful instrument of its class in the world, a gift of the late Miss Catherine Bruce, of New York; the eight-inch Bache photographic telescope; a five-inch refractor, and several smaller instruments of different kinds.

In general the work carried on in Arequipa is the extension to the southern sky of that previously begun in Cambridge. This is well illustrated by the Harvard photometry. With the large meridian photometer alone more than a million light comparisons have been made. The greater part of this work was done in Cambridge by the director and his assistants, but about two hundred thousand observations have been made by the writer in Arequipa and elsewhere in South America. This work, planned and begun by Professor Pickering a quarter of a century ago, now furnishes not only precise determinations of the magnitudes of all the brighter stars in the sky, but also the magnitudes of certain zones of fainter stars, by which the estimated magnitudes of the stars included in the various great catalogues can be reduced to the photometric scale.

With another Pickering photometer, during the last year, several thousand light comparisons of Eros were made by the writer. Eros is that remarkably interesting little planet which at times comes so near the earth as to be our nearest celestial neighbor. Eros is a variable planet, undergoing striking changes in light. The above observations showed that during the year 1903 the complete light-cycle was only $2^h\ 38^m\cdot 6^s.1$. If these changes are due to the rotation of the planet, the true period may be that given above, or, more probably, twice that amount, $5^h\ 16^m\ 12^s.2$.

Visual observations of variable stars have been regularly carried on since the establishment of the station, although the results have not yet been published. These observations are now made by Messrs. Manson and Wyeth. A determination of the longitude and latitude of the station was made in 1897 by Professor Winslow Upton, of Brown University. The result was, longitude $4^h\ 46^m\ 12^s$ west of Greenwich. The latitude is south $16°\ 22'\ 28''$. The longitude of the observatory in Cambridge is $4^h\ 44^m\ 31^s$. It follows, therefore, that Arequipa is about thirty miles west and four thousand miles south of Cambridge.

Photographic work has always occupied a large share of the time at Arequipa. Several photographic instruments are kept employed

throughout the whole of every clear night. The photographs thus made are usually examined in Cambridge, where a number of assistants are employed for the purpose. Only in exceptional cases is more than a preliminary examination made in Arequipa.

The largest instrument in the observatory is the twenty-four-inch Bruce telescope. This telescope is a doublet, that is, it has a combination of four lenses, giving good definition over a large field. The scale is the same as that of the instrument used in the international photographic survey of the sky, but the region covered by each plate is six times as great, so that the work of covering the whole sky is much less. With such instruments the work of making a photographic *Durchmusterung* of the stars to any desired magnitude would be comparatively simple, since a pair of these telescopes, one in the northern, and the other in the southern, hemisphere could furnish all the plates needed within two or three years. The Bruce telescope, after a year's trial in Cambridge, was mounted in Arequipa, in 1895, by the writer. Nearly the whole sky has been photographed with exposures of ten minutes, showing stars to about the eleventh magnitude. Good progress has also been made on plates having exposures of sixty minutes, which show stars to about the fifteenth magnitude. A set of plates has also been begun, having exposures of four hours. These can only be made on moonless nights, and a number of years will be required to cover the whole sky. The approximate number of stars has been determined on some of these plates. The number varies, in general, from one thousand to ten thousand stars per square degree. Four hundred thousand stars have been photographed on a single plate. The whole number of stars which will be recorded in this splendid set when completed will probably approach one hundred millions. In addition to such vast numbers of stars, these plates will also contain numerous star clusters and nebulæ, together with occasional asteroids, comets and meteors. This set of plates alone would furnish two or three astronomers with materials for a lifetime of study. A large part of the plates thus far obtained with this instrument have been made by Dr. Stewart and Mr. Frost.

An instrument, which has been in constant use since the beginning of Professor Pickering's photographic researches in 1886 is the Bache telescope, which has an aperture of eight inches, and a focal length of four feet. It was employed for several years in Cambridge, then for a year and a half on Mount Harvard, and since that time in Arequipa. Altogether, more than thirty thousand photographs of the stars have been made with this instrument. By its use with an objective prism photographs of the spectra of all stars to about the eighth magnitude have been made. A study and classification of these spectra have been carried out by Professor Pickering as a memorial to the late Dr. Henry

Draper. The funds for this research were furnished by Mrs. Draper. From a study of the spectral peculiarities of the stars thus photographed, Mrs. Fleming has discovered a large number of variable stars and several new stars. Charts of the southern sky are made with this instrument each year. This work is in extension of that done in Cambridge for the northern sky. This collection is now of great value in tracing the history of any newly discovered celestial object.

THE BRUCE PHOTOGRAPHIC TELESCOPE.

A similar but more frequent photographic survey of the sky is also made by means of a Cooke lens with an aperture of about one inch. Photographs are made each month with this instrument of the available sky. An exposure of one hour shows stars to about the eleventh magnitude, and a plate eight inches by ten covers a region more than thirty degrees square, or about one fortieth part of the whole sky.

The thirteen-inch Boyden telescope has been used photographically for the detailed study of the spectra of the brighter stars, and for charts of special regions. The power of this instrument is such that, by the use of a battery of two or three prisms, spectra of the bright stars are obtained several inches in length, which show hundreds of lines. By an examination of these spectra several spectroscopic

binaries have been discovered. As the objective prisms employed do not permit the use of a comparison spectrum, the binary character is apparent only when both the components are bright. In such cases the lines of the spectrum are alternately single and double. A study of the spectra of the southern stars photographed with this telescope has been made by Miss Cannon as a part of the Henry Draper Memorial.

The focal length of this telescope is about sixteen feet, so that an arc a degree in length in the sky is represented on the photographic plate by a line more than three inches long. The scale of the instrument is thus very suitable for the details of nebulæ, and for nearly everything except the centers of the densest clusters. For long exposures on difficult objects, such as globular clusters, the telescope must follow the stars in their diurnal motion with great precision. This can only be accomplished with such an instrument by watching a star visually and keeping it constantly bisected by the lines of a reticle. Formerly, a secondary telescope was used for this purpose, but, due to the flexure between the two tubes, and perhaps for other causes, really fine photographs were not obtained with this telescope until a lens for following was inserted into the field of the main instrument, so that the other telescope was dispensed with. In all cases the mean movement of the telescope is provided for by carefully devised and well-constructed clockwork; and in the case of small and rigid instruments this alone serves fairly well, unless the exposure is more than an hour.

More than five hundred variable stars have been discovered by the writer in the globular clusters, by means of charts made with this instrument. These constitute nearly one half of all the variable stars known, but they all occur in only one thirty-thousandth part of the sky. At the centers of some of these clusters, the stars are packed together so densely that there are one hundred stars to the square minute. If the stars were equally dense over the whole sky, their number would exceed ten billions, and the sky would be so luminous that there would be no real night. In one of these clusters, Messier 3, one hundred and thirty-two variables were found. These are all situated within a circle whose area is one fourth of a square degree, or only one one-hundred-and-sixty-thousandth part of the sky. In this cluster one star in seven is variable. The photographs used for this investigation must be made with the greatest care, and must then be enlarged, or else examined by a microscope, since the images of the stars on the original plates resemble thickly scattered grains of dust.

The duration of exposure employed varies enormously, according to the instrument and the object to be attained. They have been made from one second up to twenty-four hours. With the great Bruce lens, an exposure of one second is sufficient for the brightest stars, while an exposure of four hours, or more than fourteen thousand times as long,

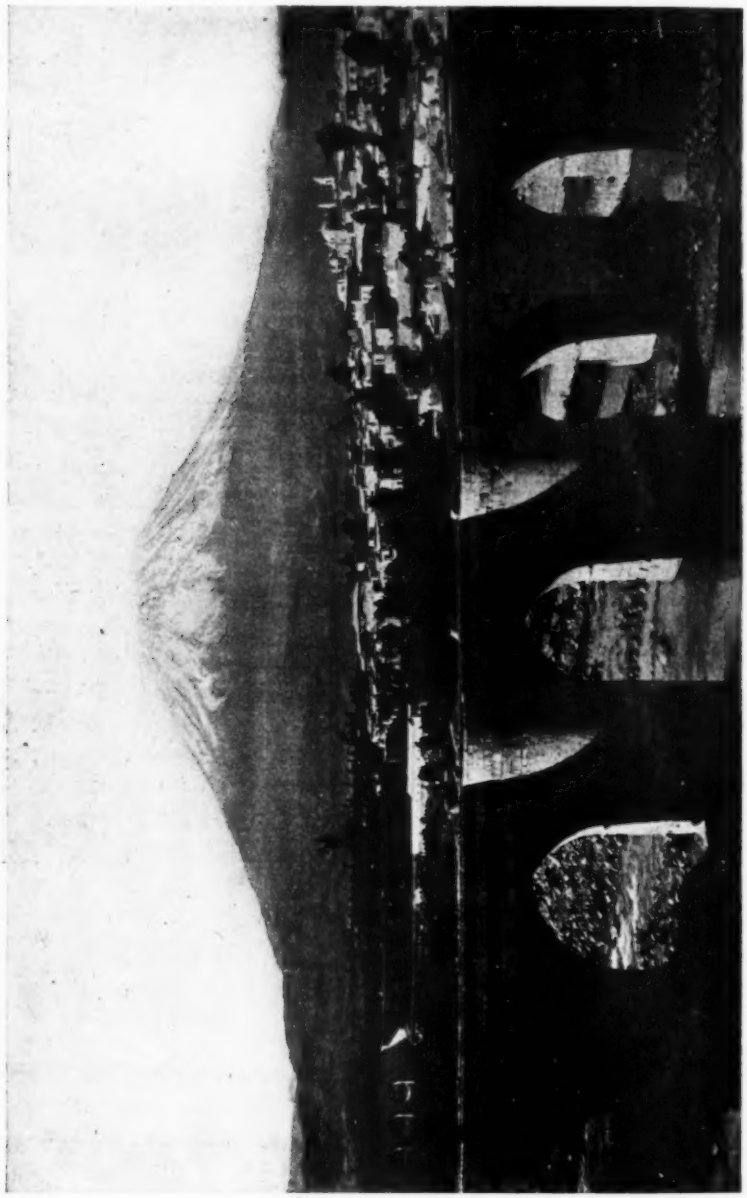
fails to record stars which will appear when an exposure of five or six hours is used. For the comparatively bright stars, the number increases approximately by the ratio three for each magnitude. For example, there are about three times as many stars of the second magnitude as of the first, and three times as many of the third magnitude as of the second. There are indications, however, that this ratio is not kept up for the fainter stars, that is, there are not three times as many stars of the sixteenth as of the fifteenth magnitude. No limit to the universe has yet been reached, however. With the Bruce telescope stars can be photographed too faint for vision in the greatest

THE METEOROLOGICAL STATION ON EL MISTI. 19,000 FT.

telescopes of our day; but increase in exposure always brings out new and fainter stars, until the practical limit of the exposure is reached in the fogging of the plate by the diffused light of the sky. The longest exposure yet made in this observatory was with the Cooke lens, an exposure of twenty-four hours, on four different nights. Such an exposure in such an instrument brings out with great perfection the wonderful beauty of the cloud-forms of the Milky Way.

Since the establishment of the Peruvian station, meteorology has formed an important, though subordinate, part of the work. For about ten years a line of auxiliary stations was maintained, reaching from the Pacific across the Andes to the low country on the upper waters of the Amazon. The culmination of this series was the station

on the summit of El Misti, at an elevation of nineteen thousand feet. The conditions for reaching great altitudes are exceptionally good in



THE CITY OF AREQUIPA.

this part of Peru, but even here it was found impossible, with the funds available for this purpose, to keep observers at the summit, in order to obtain systematic personal observations. It was necessary to depend

chiefly on the self-recording instruments of Richard Frères. The station was established by the writer in 1893, and was visited later by different members of the observatory, or by some person engaged especially for the purpose. At such visits the observer rewound the self-recording instruments and made personal observations. This station was continued for about seven years. The records were broken, and not always of the highest accuracy, but it is believed that they will be of service to meteorology. Personal observations of the highest precision at this station are much to be desired, but a special gift for this purpose would be necessary. Few persons could live, even for a few days, at such an altitude. Nearly every one suffers from mountain sickness, and sometimes very severely. Nevertheless, there are sufficiently well educated persons, born in Peru at a high altitude, who could be engaged for a reasonable sum to pass alternate weeks at the summit. In this way, for a few thousand dollars, complete records of great precision and value to science might be obtained. There are also problems in astronomy and physics, which could be investigated at a well-equipped station at such an altitude, which perhaps can never be solved at sea-level.

Arequipa is a city of about thirty thousand inhabitants. It lies on the western slope of the Cordillera at an elevation of seven thousand five hundred feet. No more beautiful view can well be imagined than that which is seen as one approaches Arequipa from the coast. It is built of a soft white volcanic stone, and in the distance appears to be a city of marble. It is surrounded by wide-spreading green fields of wheat, corn and alfalfa. It is in a region of volcanoes and earthquakes, but the danger from these is slight, either to observers or to instruments. The observatory is situated on rising ground, about two miles north of the city, at an elevation of eight thousand feet above sea-level. To the north rises the great range Chachani, about twenty thousand feet in elevation; to the northeast El Misti, a volcanic cone nineteen thousand feet high; and to the east Pichu-Pichu, over seventeen thousand feet high.

The climate of Arequipa is superb for those who do not object to a somewhat rarefied and dry atmosphere. There is scarcely any seasonal change in temperature during the year, though the diurnal range is fairly large. The mean maximum and minimum temperatures for the year 1902 were 68° and 49°. In the observatory residence, which is built of stone, the temperature without artificial heat ranges between 60° and 65° Fahrenheit. The rainfall is slight, amounting to only two or three inches during the year. Agricultural pursuits are possible only by means of irrigation. Around the fertile fields, in whose center lies the city, extend endless barren pampas. All the waters of the Chili River, however, are now well utilized, and there is no other convenient supply.

The people of Peru, and especially of Arequipa, have always taken great interest in the observatory, and have extended to it many favors and constant good-will. There is a university in the city of Arequipa which is supported by the Peruvian government. There is no lack of educated and refined Peruvian society, and in addition there are American, English and German colonies. The laboring and servant classes are half-breeds, usually illiterate and careless, but kindly and contented. Besides these, especially in the interior, are large numbers of civilized Indians. In the low lands lying about the head waters of the Amazon are also numerous groups of savages, but they are never seen near Arequipa, and are slowly becoming half-civilized or disappearing. Revolutions have been numerous in the past history of Peru, and one occurred since the establishment of the station in Arequipa, but not the slightest indignity was offered to the observatory or its members. The common people of Peru, even in time of revolution, are not dangerous, and those who are not actually engaged in warfare are seldom molested. It is a game of politics, carried on by bullets instead of ballots, and without permanent hatreds. For several years past no revolution of importance has occurred, and there are strong indications that Peru has at last entered on a career of peace and prosperity. Such, at least, is the earnest wish of her best citizens.

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE AND THE FINE ARTS. BERLIN.

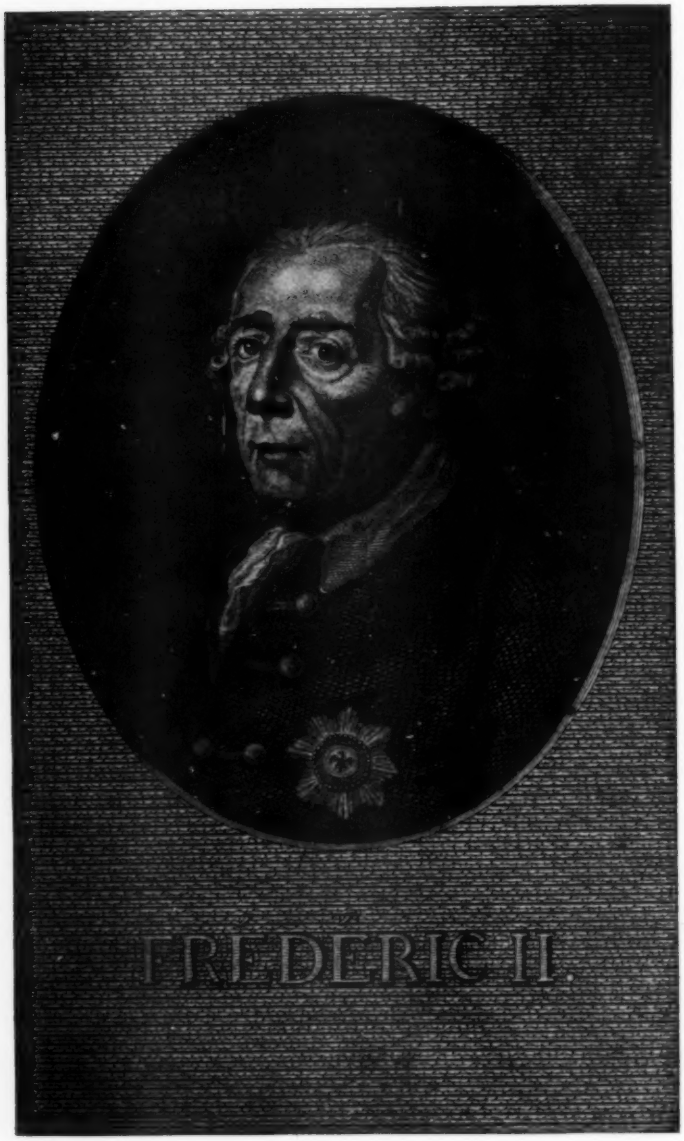
BY EDWARD F. WILLIAMS,
CHICAGO, ILL.

II.

History of the Royal Prussian Academy of Science and the Fine Arts from its reorganization under Frederick the Great till his death in 1786.

UNDER the patronage of the new king, which was continued with increasing sympathy during the forty-six years of his reign, the academy in Berlin acquired world-wide influence. The Literary Society of Berlin, which had been a serious rival, was united with it, and the new organization was named The Royal Prussian Academy of Science and the Fine Arts. The king had intended, it is thought, that Voltaire should be its president, but for some reason, greatly to the mortification of the Frenchman, Francis Algaratti, of Paris, was given that honor. But he did not retain it long.

The king was anxious to have Wolff, the philosopher, in the academy as a representative of the thought of the new time, and Maupertuis, of Paris, as a representative of the attainments and the spirit of Sir Isaac Newton. Wolff did not care to leave his professorship in Halle, and though Maupertuis was made one of 'The Immortals' of the French Academy in 1743, he came to Berlin in 1741, and at the king's wish, assumed control of the academy and continued at its head till his death on July 17, 1759. In 1743 the last volume of the Berlin 'Miscellanies' was issued. The academy now entered thoroughly into an era of reorganization. Its publications became cosmopolitan in character. Even if expenses increased the income grew. Men of distinction began to think favorably of Berlin as a home, and of membership in the academy as desirable. New societies for the study of natural history and literature, for which the inefficiency of the academy had furnished an excuse, were united with it on the broad plan of Leibniz. In the reorganized institution there were to be classes for the study of physics, mathematics, philosophy and philology, with a director at the head of each class. There were to be 24 members, and these were to be selected by the king from lists of names placed in his hand. The members of the old academy were all retained, but new men of the highest standing only were granted membership in the new institution.


FREDERIC II.

Each class had the privilege of choosing its own secretary or director, but in addition there was to be a general secretary entrusted with the business and general interests of the academy. A treasurer was also appointed and provision made for two public meetings every year, one on the king's birthday. In later years one of these public meetings has been held on what is called 'Leibniz day,' July 11. Sessions were held weekly on Thursday afternoons. New members were nominated by the class they were expected to join, but the nomination had to be approved by the directory of the academy, which was made up of five secretaries and other officers, then by a general meeting of the academy and last of all by the king. It was decided that prizes should be offered every year and that papers of foreigners, if worthy, should be printed in the proceedings, as well as those by the active or honorary members of the academy. By the king's order the sessions of the reorganized academy were held in the castle. They began on January 24, 1743.

It is difficult to give a full history of the academy while Maupertuis was at its head. He preserved few papers. Although the roll of officers was full, he was really the academy. It was through his influence that men of distinction abroad became corresponding or honorary members, and some, at his solicitation, even came to Berlin that they might work in it and through it.

Deeply interested in the academy and writing papers to be read in its literary department, the king attended neither its private nor its public sessions. Nor till toward the end of his reign did he bid any of its members, save Maupertuis, to his palace. Even Formey, the famous secretary, was not called to Sans Souci till the king had been thirty-eight years on the throne. The social circles in Berlin and Potsdam were not quite the same. Maupertuis made the academy French in its thought and its aims. Under his guidance and that of his successors it was composed of a group of French scholars residing on German soil. Maupertuis was one of the most gifted men of his generation. He had great learning, was a diligent student of natural history and possessed rare powers of conversation. But his influence was lessened by his egotism and his pessimism. Still he did his best for the academy. Its 'Memoires' were sought for in every learned circle in Europe. Membership in it was regarded by scholars as the highest honor they could receive. Its atmosphere was tolerant. There were no limits put upon research or upon free speech. Though German was not absolutely excluded, the discussions carried on in the academy were in French and the 'Memoires' were printed in French. There were more French-speaking Swiss in the academy prior to the death of Maupertuis than native-born Frenchmen or Germans. Switzerland was producing more learned men than she could sustain, and was willing they should go to Berlin or wherever else they might employ their talents to advantage.

The academy suffered from the seven years' war (1756–1763), but its regular work continued, though few new members were added during this period. From 1760 to 1764 no 'Memoires' were published. While Maupertuis was absent on account of the wars and in search of health, Euler acted as president, and proved himself well qualified for the duties of that office. But the king had no intention of filling it with a German. The man he wanted was d'Alembert, of Paris, to whom he offered a large salary, rooms in the palace and a seat at the royal table if he would come to Berlin. But d'Alembert belonged to the French Academy and did not care to leave Paris. Yet, through his correspondence with the king, in which during these years the best history of the academy is found, he directed the work of the German academy and determined its membership. Virtually he was its president, though the king as its protector may be said to have assumed that office himself. In these conditions the academy became more French in its spirit than ever. In spite of the fact that the forty-six years of Frederick's academy were years of the first importance for the development of science and literature in Germany, neither the king nor his French presidents took any notice of the new spirit which had arisen among the German people, and had begun to show itself in the academy. Euler, disappointed at the turn matters had taken, after twenty-five years of hard work in Berlin, asked leave to return to St. Petersburg. For a time the king declined to grant the request, but its renewal finally secured his assent, though without any recognition of the fame Euler's attainments and publications had brought the academy and Berlin. Ten years later, on accepting honorary membership in the St. Petersburg Academy, at that time a rival of the Berlin Academy, the king wrote Euler a letter accepting the honor secured for him, and in it made something like an atonement for former neglect. La Grange, of Turin, second only to Euler as a mathematician, was elected to the vacancy Euler's departure had made, and about the same time J. Heinrich Lambert, another mathematician of note, came into the academy. Prior to d'Alembert's connection with it the Eulers, father and son, Pott, Marggraff, Gleditsch, Merian, Sulzer and Suessmilch had given it fame. Other men of rare ability had been persuaded to come to Berlin with the promise of membership in it, but with the understanding that they were to teach in the Ritterakademie, an institution in which the king took much pride and which he founded.

Not many changes in the academy took place during the last sixteen years of Frederick's reign. Between 1766 and 1770 two volumes of 'Memoires,' which the war had prevented from appearing, were published. With the next issue a new series of 'Memoires' was begun, greatly improved in binding and paper. Each of these new volumes contained a brief history of the work of the year.

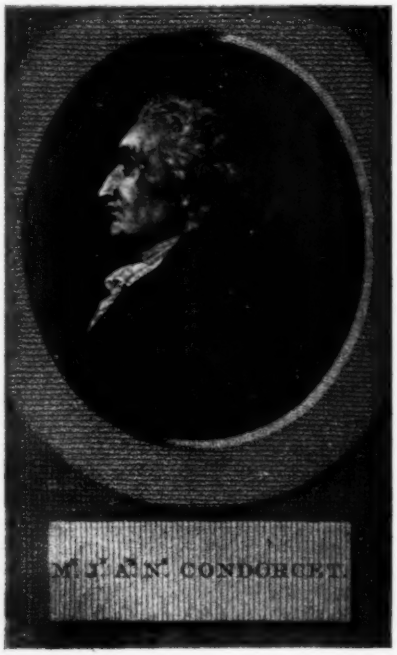
D'Alembert died on October 29, 1783, sincerely mourned by the king. He had rendered the academy as good service as any one could, living in Paris. He and the king had not always agreed in their policy. D'Alembert not only desired the utmost freedom of research, he wanted the whole truth as it appeared to be at any particular time

PIERRE-LOUIS MOREAU DE MAUPERTUIS.

given to the people. To this the king would not consent. He often quoted Fontenelle's saying, 'If I had my hands full of the truth I would not open them to give it to the people. It would not pay for the trouble.' Harnack says the chief aim of the king was the welfare of his subjects, and that, free thinker as he was, he was no atheist and would not accept the opinions either of Hume or Holbach. He loved

the truth, and did not mean to withhold it from the people forever. But he believed in preparing them to receive it before giving it to them. Hence in part his interest in education, and an explanation of the famous rescript of September 5, 1774, which, as carried out by Minister von Zeidlitz, became the foundation of the improved methods in Prussian teaching. Logic, the king wrote, must be taught effectively after the manner of Locke and Quintilian, and Latin and Greek in such a way as to bring young men into their atmosphere.

The sincerity with which the king held his opinion as to the proper treatment of the people is seen in the fact that he directed the academy to offer a prize for the best answer to the question, 'Is it lawful, *i. e.*, right, to deceive the people?' At the time of d'Alembert's death the philosophical class in the academy had shrunk to three members. Again turning to a Frenchman for help the king asked Condorcet, permanent secretary of the French Academy, to take d'Alembert's place in directing the work of the Berlin



IMMANUEL KANT.

Academy. Condorcet consented, but the new relation lasted only sixteen months.

It had at length become evident to all German scholars that their academy needed new blood. Its men of fame were growing old. They had done their work and had lost in a measure their ambition. The king was growing old also. The changes so necessary and so greatly desired came, but not till after a new king was on the throne. When Frederick died, only five Germans belonged to the academy—Gleditsch, Gerhardt, Roloff, Walter and Schulze—and they had little influence in its councils. It is not surprising that many felt that it was a discredit to Germany that Germans should have so small a part in determining the character and directing the work of one of their representative institutions. It was time, men said, that Germans should be at the head of a German academy of science. It had been ruled long enough by absentees. Even Leibniz had resided in Hannover during his presidency, though he had visited Berlin as occasion demanded and, being a German, had sought to develop the German spirit. This had not been the case with Maupertuis, or d'Alembert, or Condorcet. Hence the demand for such a reorganization of the academy as would make it thoroughly German and representative of German intellectual life. The change, so uniformly desired, was brought about by one of its members, Minister von Hertzberg, who was made its curator by Frederick William II. at the very beginning of his reign.

Before passing to consider the history of the academy under the successors of Frederick the Great, who died on August 17, 1786, and in its distinctively German period, something should be said concerning the contributions to learning and the new thought which its members had made. There can be no question that the papers written by the king, for the department of fine arts, and read by some one whom he designated, are among the most valuable possessions of the academy. This is one of the reasons which has led the academy within recent years to prepare and publish a complete and worthy edition of his writings.

From the beginning the academy sought to advance science and encourage sound learning in Germany. That this was so long done under the direction of Frenchmen did not really affect the result. But much as members of the academy were enabled to do for science and literature through the publications and reports of the academy, they did far more as individuals, and by private publications. Early in his reign Frederick the Great expressed a wish that the members of the academy would give the results of their studies and experiments to the public in the shape of lectures, and, though this was not generally done, lectures were given by Gleditsch, the botanist and the founder of the botanic garden of Berlin, to the medical students, and, at the same

time, other members of the academy made their discoveries known to the people. Thus Gerhard lectured on mineralogy, metallurgy and the theory of mining, and Achard on chemistry, experimental physics and electricity, so that by 1780 there was a university in Berlin in everything save name and organization.

After 1744, through the subjects proposed for prizes, the academy became a sort of guide in study and research for some of the best minds in Europe. Small as the prizes were, fifty ducats at first and after 1747 a gold medal, they were contended for by the most eminent scholars and thinkers of the day. Such men as Euler, La Grange, d'Alembert, Kant, Rousseau, Herder, Lessing and Moses Mendelssohn entered the lists for them. In general, the themes proposed required a thorough knowledge of an entire discipline and a discussion of its fundamental principles. For the prize of 1780 forty-two papers were sent in. During the forty-six years of Frederick's reign 26 German works were crowned, and 10 French. One written in Italian received the prize. Of 45 themes treated, 20 were medical or physical in their character, and 25 philosophical, philological or literary. It is a fact worthy of note as indicating the intellectual attainments of the ministry of the period, that ten of thirty-eight works winning the prize were written by ministers of the Reformed or Lutheran church. In the twenty years following this period the average was even higher.

The eighteenth century was not favorable to exact historical study. It was fortunate, therefore, that the academy continued to offer prizes for the discussion of historical themes. The spirit of the time was philosophical rather than scientific or historical. The successful didactic poet was in most circles thought to have realized the highest ideal of life. The writings of Rousseau, Kant and the German idealists were the means of extending the range of thought, giving it a new direction, and of introducing a series of questions which demanded immediate and thorough answer. Advocates of the Leibniz-Wolff philosophy were opposed by the followers of Newton and the French school. For a number of years themes were presented by the academy which seemed to have for their object the overthrow of the philosophy of Leibniz, and the substitution of that of Newton in its place. But these were not the only subjects discussed. J. D. Michaelis, the orientalist, won the prize for 1759 by pointing out, in the best way possible at the time, the reciprocal influence of the people on their language, and of language upon opinion. In 1763 Moses Mendelssohn answered, in a manner which satisfied the academy, the question, 'Is metaphysical knowledge susceptible of the same evidence as mathematical?' and received the prize, though he had no less a rival than Immanuel Kant. Yet the rejected essay of Kant gave the death blow to the philosophy of Wolff. Cochius, court preacher at Potsdam, re-

ceived the prize in 1768 for an essay on the topic, 'Is it possible to destroy natural inclination, and how may one strengthen the good and weaken the bad?', but even here it was Kant who stated the problem so effectively as to overthrow the philosophy of the *Aufklärung* and to establish ethics upon a new and firmer basis. The origin of language was discussed in 31 treatises in 1769, and the prize awarded to Herder, who took the ground that it is neither divine in its origin nor an invention of men, but a gradual growth springing out of the necessities of human nature and therefore imperfect and incomplete.

One hundred years later this essay received the approval of Jacob Grimm. In 1775 Herder won a second prize by an essay on 'The degeneration of taste in various peoples,' and in 1780 on the theme, 'What has been the influence of government on letters among the nations where they have flourished, and what influence have they had on government?' These essays were epoch-making for historical study. In 1784 the theme was, ' What has made the French language the universal language of Europe, or by what means did it win this prominence? Can we believe that this prominence will be permanent?'

Lambert, a man whom Kant regarded as the greatest genius of his time and in whose judgment as a critic he had complete confidence, died in 1773, after a membership in the academy of thirteen years. While he lived he read all that Kant wrote before it was given to the world. He composed essays for three of the four classes into which the members of the academy were divided, published in addition to these papers, fifty-two treatises, perhaps one hundred pamphlets, and ten very large works. Not a little was accomplished by the academy during these years for geology and mineralogy, as well as for astronomy and mathematics. Pott made the academy famous in chemistry, but Marggraff and Achard were large contributors to the science. Walter succeeded Meckel, the anatomist, in 1773, and laid the foundation by his splendid achievements of the anatomical museum of the University of Berlin. Neutral as the academy was in its philosophy, it yet prepared the way for Kant and the general acceptance of his opinions in Germany. It was equally neutral in religion, and in morals it sympathized with the king, who admired, and probably made his own, the opinions of Marcus Aurelius and the Stoics. The academy, through Maupertuis, Euler and La Grange, made the works of Newton known to Germany, and in this way, as well as in many other ways, stimulated and directed the scientific movement among all the German-speaking peoples.

Some idea of the industry of the members of the academy may be formed if we observe the number of works credited to them in its catalogue. The secretary, Formey, leads with 140 titles. John Gottfried Gleditsch has 36 titles. To Gerhard, the geologist, there are

given 21 titles, while the younger Kirch, the astronomer, has 27 titles. Euler, in the quarter of a century he lived in Berlin and worked in the academy, published in its transactions 121 complete treatises, through other channels at least 700 more, and, in addition, was the author of 32 quarto and 13 octavo volumes. La Grange, his successor, the discoverer of the calculus of variations, during the thirteen years of his life in Berlin published 52 important treatises, about 100 pamphlets and 10 large works. From 1746, when the era of publication really began, to 1771, 25 volumes of 'Transactions' appeared and 65 volumes of what are called historical writings. The publications were even more important between 1771 and 1786. The income of the academy at the death of the king was nearly $18,000, devoted, it was supposed, entirely to the discovery and extension of knowledge, and yet, as a matter of fact, expended to such an extent for buildings and the payment of salaries at the order of the king as to leave comparatively little for the support of original investigators, or for costly experiment and research. In fact the management of the academy, even under Frederick the Great, was so unsatisfactory as to furnish excuse for the formation of many learned societies in Berlin, in some of which members of the academy took a leading part. Thus in the philosophical society, which flourished from 1773 to 1798, men like Mendelssohn, whom the king would not have in the academy, Nicolai, Teller and Engel were prominent, and a society of naturalists was formed during this period by the aid of Gleditsch, the botanist, one of the famous men in the academy. Yet with all its failures, and the fact that it was so completely under French influence, there can be no doubt that the Prussian Academy of Science and Fine Arts at the death of Frederick the Great had become the center of the scientific and critical movement in Germany, and was regarded all over Europe as a worthy rival of the Royal Society of Great Britain and of the French Academy in Paris.

THE INFLUENCE OF LIEBIG ON THE DEVELOPMENT OF CHEMICAL INDUSTRIES.*

By Dr. CARL DUISBERG,

DIRECTOR OF THE FARBENFABRIKEN VORM. FRIEDR. BAYER & CO. AT ELBERFELD.

THE chemical industry is a child of the nineteenth century. The inorganic branch, the so-called industry of heavy chemicals, such as the manufacture of sulphuric acid in lead chambers, the manufacture of nitric acid, of hydrochloric acid, of sulphate, the manufacture of soda according to Le Blanc's process, the manufacture of chlorine and bleaching powder according to the processes of Deacon and Weldon, was already in operation in the first part of the nineteenth century, while the organic branch of the industry, the manufacture of coal-tar products, of the organic intermediary products, of the aniline and alizarine dyestuffs, pharmaceutical and photographic preparations, the artificial sweeteners and artificial perfumes, and the whole crowned by the synthesis and manufacture of indigo on a large scale, became known only in the latter part of the last century.

As Liebig's influence on the education of chemists and on the chemical industries was chiefly exercised during the time he lived in Giessen, that is until about 1860, and as this influence became of course perceptible only very gradually and slowly, it is evident that the *organic* chemical industries owe most of their progress to Liebig, and therefore I shall devote my remarks chiefly to a description of this influence.

As every branch of industry is originally the result of empirical research, it is very rare for men of great scientific knowledge to become the founders of any new industry. We find that almost invariably energetic and enterprising merchants, who possess some technical skill, are at the head of such undertakings; and thus we find at the beginning merchants as managers of the factories of the organic chemical industries. Scientific research pointed out the direction in which the gold fields were to be discovered, and enterprising and energetic men marched on the road indicated to the unknown regions, provided with the simplest tools, to uncover the golden treasures and to free them from the gangue which hid them from the view of mankind.

* An address delivered before a joint meeting of the New York Sections of the Society of Chemical Industry, the American Chemical Society, the Verein Deutschen Chemiker and the Chemists Club, held in celebration of the one hundredth anniversary of the birth of Justus von Liebig.

This was the case with the first works for the distillation of tar, as well as with the coal-tar color factories. Tar was *not* distilled and split up into its various component parts according to principles which were founded on rational and exact chemical research, the different hydrocarbons thus obtained were *not* nitrated, reduced, sulphonated, condensed, etc., in order to be converted into intermediary products and dyestuffs by processes discovered by the scientific investigator. These operations were executed by the rule of thumb, by men who had been engaged in kindred industries, in metallurgical works, in dyehouses, or in pharmacies or drug houses. These men worked in mere sheds, with vessels which for the most part were taken from the kitchen. There were no chemists; there were no laboratories. If it became necessary to analyze the inorganic crude materials which were used in the manufacture, it was done in a remote dark corner of the factory by so-called chemists, who were only educated in analytical schools. Instant dismissal was the penalty at that time imposed upon any chemist who dared to enter any of the rooms where the manufacturing was going on, to try to familiarize himself with the processes for the preparation of various products. The supervision was exercised by so-called practical men, who were ignorant even of the simplest principles of scientific chemistry, who derived their methods for the manufacture from mechanical experiments and who kept the formulæ a deep secret, just as the alchemists concealed their receipts for the art of making gold.

Meanwhile Liebig had shown by his work in the laboratory in the quiet and far-away Giessen, by lectures and publications, what important treasures could be found in all branches of agriculture and industry by scientifically educated chemists well trained in laboratory methods, in analyses and syntheses of chemical bodies. He had shown that a knowledge of general chemistry and of its scientific principles and practical methods enabled men to advance all branches of the industries.

Liebig's staff of excellent pupils made their way to all quarters of the globe to disseminate his ideas and to assist agriculture and the industries. The light of scientific research kindled by Liebig penetrated all branches of industry. It pierced into the darkest factory rooms which were guarded with many secret locks, and more and more the truth of Liebig's teaching became recognized, that agriculture and the industries would accomplish undreamed of results, if scientifically educated chemists were employed in all branches and were permitted to exercise control of all methods.

In consequence thereof we now see that these large factories, devoted to the chemical industries which have drawn into their circle the manufacture of all the heavy chemicals, the production of the intermediary

products from the distillation of wood and coal-tar, the finished materials being aniline and alizarine dye-stuffs, indigo, pharmaceutical and photographic products, artificial sweeteners and artificial perfumes, are managed exclusively by scientific chemists. The practical man was forced to yield to the well-educated theoretical man.

Laboratories in which are to be found all the modern apparatus and implements of science and technique have taken the place of the dark cellars in which chemists were formerly imprisoned; magnificent libraries are at the disposal of the investigating chemist of the works, and everywhere Liebig's spirit rules and everywhere Liebig's methods are practised.

How much importance the German chemical industry attaches to the exclusive employment of scientific men, how these are educated at the universities and polytechnics, and what means are employed to maintain the scientific standard of the chemist, all that I had the honor of pointing out in a lecture, delivered seven years ago during my first visit to the United States before the New York Section of the Society of Chemical Industry. Meanwhile the number of chemists employed in our German factories has not only increased considerably, but we have also raised the requirements in the education of chemists whom we employ in our factories and laboratories. Where seven years ago, as I then stated, our factory, the Farbenfabriken vorm. Friedr. Bayer & Co. at Elberfeld, had only one hundred chemists, educated at German universities or high schools, we have now over 160 in our employ.

A systematic organization, founded on a scientific basis, encircles our works. No effort is omitted to bring to the notice of all the chemists every advance of science, so that they may utilize it for the benefit of our factory, and every new technical method is at once thoroughly investigated in order thus to gain new knowledge and create new products.

The details of such an organization are most interesting. The control of all raw materials, delivered at the works by water or rail and of all the intermediary products, are carried out by a central laboratory, which is devoted to analytical chemistry exclusively. In this laboratory a large force of analytical specialists is employed. Here are analyzed not only products which are bought by us, but also intermediary products which are furnished by one department of our works to another, and the exchange of goods within our factory is carried out by contracts which are concluded between the various departments. The analytical methods which are to be used and the conditions of the contracts are perhaps more stringent than if the material had been purchased from outside factories. When no an-

alytical methods exist, as is frequently the case with new products, it is the task of the analytical laboratory to devise such methods, and the work demanded of our analysts is just as important and difficult as the task of any other chemist in our employ. Our analytical chemists must have the same scientific education as the others, and we consider them in position and rank on a par with any other chemist.

The manufacturing is of course in the hands of first-class chemists. The factory is divided into different departments. At the head of each department one of the most experienced chemists is placed as department chief, and he manages his section as a factory in itself. Thus our works are divided into the inorganic department, the departments for intermediary organic products, for aniline colors, for alizarine colors and the pharmaceutical department.

Each of these departments consists of a number of separate divisions which are again under the management of chemists, all of whom we have trained ourselves. The chemists of the different divisions belonging to one department have a joint laboratory whence they conduct the various manufactures, their main object being economical production and good yields. Each step of the reaction is continually watched analytically, and thousands upon thousands of experiments are constantly carried out to improve the processes and above all the quality of the manufactured products. These chemists have also charge of the machinery used in their departments, and a scientific engineer acts in conjunction with them.

Commercially educated employees control the consumption of chemicals of all kinds in each department, and based on their figures, and the figures of the consumption of water, gas, steam, ice, compressed and rarified air, etc., used in the processes, exact calculations are made for each product monthly. Furthermore, there are scientific laboratories, one for inorganic chemistry, another for coal-tar colors of the benzine and naphthaline series, a third for those of the alizarine and anthraquinone groups, another for pharmaceutical and photographic products. In these laboratories all reactions which seem to be of technical importance and which have been described in scientific and technical journals are tested as to the value. All the patents, issued in the various countries, are studied and their processes executed on a small scale. The new products which appear in the market are analyzed and investigated in order to determine their constitution and their practical value and to ascertain whether they can be utilized in the manufacture of any new products. It is further the duty of the heads of these scientific laboratories to inform not only the chemists who are working under them, but also the other works chemists, of everything new in chemistry, scientific as well as technical, and regular

meetings are held, where reports are made on all new discoveries and publications.

The finished products of each department, both the coloring matters and the pharmaceutical and photographic products, are tested as to their efficiency in laboratories especially equipped for the purpose. The controlling laboratory for coloring matters is provided with all the machinery and apparatus used in first-class print works and dye houses. Here the coloring matters are practically applied, and it is ascertained whether they come up to the requirements or not, and only when their standard has been determined are they permitted to leave the factory. A very important part of the work of these control or testing laboratories consists in examining the many new products which are the results of the investigations of the scientific laboratories, as to their usefulness, and to find new methods of application for the older products.

As the colors are tested in the dye laboratory, so the pharmaceutical products are investigated in the pharmacological laboratory, at the head of which we have at our Elberfeld works a prominent representative of this science, who was a teacher of pharmacology and physiology at the University of Göttingen. His assistants comprise four physicians and two bacteriologists who are constantly carrying out animal experiments on frogs, rabbits, cats, dogs, etc.

It will be seen therefore that scientific and systematic research has in Germany taken the place of empirical experiments. Although every chemist is a specialist in his own branch, he is enabled to find his way in any other special line of chemistry on account of his thorough general education and the constant accessions to his knowledge.

We should never have reached and would surely not have been able to maintain the high standing which the German chemical industry holds in the world now-a-days, unless this scientific bent of mind, which seems to be a particular quality of the German national character, had governed our work.

As I did seven years ago, so I have this time taken a four weeks' trip through this beautiful country, and have seen many of the American industries. Owing to the extraordinary hospitality and courtesy of the inhabitants of all the cities visited, we have been allowed to inspect almost all the great branches of American industry. Aside from the various and magnificent textile works of the south and the east, we have seen the largest steel works and iron foundries, refineries of petroleum, glass factories, factories for all kinds of electrical appliances and machinery; and of the chemical factories we have visited some of those engaged in the production of heavy chemicals, factories of the organic chemical industry and especially those of the electrochemical industry.

It may perhaps be of interest to learn what impression your industries made on a fellow chemist, not only at his first visit, but also during the present one, and I shall not hesitate to give frankly my impartial opinion.

At first sight it alarms us Germans when we observe what tremendous natural resources this country possesses—the wealth of lumber in your forests, the fertility of your soil, the mountains, the extent of the plains and valleys—all natural storehouses of great riches. If a hole is drilled or a drift is made in the mountains in some of the states, natural gas or petroleum is found; in another the finest of anthracite coal or soft coal, which furnishes the best material for coking and distillation; in a third state we find ores of every description; in a fourth salt, or sulphur; in a fifth, deposits of phosphates which are of so much importance in agriculture, while in some of them we find a collection of nearly all these products.

This is not the case in Germany. We are not blessed with natural gas or petroleum; anthracite coal is very rare. We have immense soft coal fields, but we must go down to a depth of two to three thousand feet, whereas in America it is at the surface, or in the very worst cases a depth of only three hundred feet must be penetrated. We have minerals, but not in such masses as here, and above all they are not of that purity which facilitates metallurgical processes. Only of salt have we as much as you, and more as far as potash salts are concerned, of which we have immense fields in Stassfurt. While with us the water in rivers flows gently and softly, and even for navigation our rivers need to be constantly dredged, you have in your grand country natural water courses such as are found in no other land in this world. In addition to this, your rivers rush down high mountains, so that every stream can be made a tributary to the industries. The millions of horse-power which are available in Niagara Falls, and have been partly utilized, give your country a decided superiority over all others.

But in spite of these natural advantages Germany has remained the ruling power in chemical industries, and I may venture to say that, in my opinion, we shall retain this commanding position in the immediate future. If I am asked to give my reasons for this opinion, I must say that the answer is neither simple nor easy, but I hope to be in the right if I remark as follows:

In view of the wealth of this country in products of all kinds, but in view of the want of labor, it has been and is still the chief task of the industry and of the engineer to devise means to render these products available in the simplest and cheapest manner. This is the field of the mechanical engineer, and American engineers, indeed, have accomplished the most magnificent results in handling and transporting vast masses and in the substitution of machinery for manual

labor. This, indeed, is the essence and strength of the American industry and was the cause for the development of the mechanical industry, and in this respect America is the ruling nation and has set an example to the whole world.

But the conditions are quite different in the purely chemical branch of the industry, the object of which is to convert crude materials by means of numerous chemical processes and chemical forces into more precious ones; where a new process devised by a chemist revolutionizes the industries and makes the old processes unprofitable, even if they are performed by the most ingenious appliances constructed by the most talented engineer; where not only the art of construction, but the genius of the naturalist in recognizing the forces of nature and their products is necessary to accomplish the object in view; where never or only rarely the production of large masses comes into consideration, but where an endless chain of products of the greatest variety must be prepared in small quantities.

If I have sung the praises of the American engineer and of the American mechanical industry in the preceding portion of this lecture, I must now express my satisfaction with the German chemist and the German chemical industry. In this field lies the strength of Germany —a consequence perhaps of the peculiarity of the German character. Forced by the want of natural resources and unprovided with American abundance, the German in scientific exploration must proceed in a cautious and economical manner, always bent on patient and minute research. He is forced to live a simpler life and to be modest in his demands, which is contrary to the American temperament.

It is true you have already a very important industry in the inorganic field of our science and produce large quantities of acids and alkalies and, above all, of metals. In consequence of the immense and cheap water power at your disposal, a very remarkable electrochemical industry has been developed. But these works manufacture at present only inorganic products, and so far as I can see it is impossible up to date to manufacture organic products as economically by electro-chemistry as it is possible with the older chemical methods. You have also begun to isolate the products of tar distillation which are formed during the coking of coal, and it is intended to convert the hydrocarbons thus obtained into more intricate organic products. You have also the beginning of a coal-tar color industry, due to the protective duty of thirty per cent. ad valorem. I have also noted that in metallurgical and textile works, but above all in factories of heavy chemicals and pharmaceutical specialties, chemists exercise analytical control of the raw materials which enter into the process. At some places we found wonderful laboratories in which many chemists were employed. We saw above all how your universities and technical

schools are endeavoring to promote our science. Excellent representatives of scientific chemistry are employed as teachers. Scientific research is carried on more and more. But, notwithstanding all that, I think that we Germans need not be alarmed in the near future. The time for the development of the *organic* chemical industries on a large scale has not yet arrived. As I have shown before, the Germans are masters in manufacture where numberless products are employed in a series of reactions which finally lead to the finished product, and require manual labor, which can not possibly be replaced by machinery, while Americans may claim to be masters where manufactures on a large scale are concerned, which can be done by machinery. Yet we must not leave out of consideration the very important facts that in America wages are extraordinarily high, that the conditions of life are here much more elaborate, and last, but not least, that the employees, and more particularly the workmen, manifest a spirit of independence, which has become especially noticeable during the last few years. By their labor unions the workmen attempt not only to raise wages to a height which will make manufacturing difficult and less profitable, but they are also endeavoring to take the control of the works out of the hands of the educated managers and put it into the hands of irresponsible labor leaders. This movement, as I have above shown, is especially fatal for the chemical industry in which our glorious science should be supreme. But nobody can deny that times will change in all these respects. Then you will be obliged to husband more economically your natural treasures, and you will experience changes which with us, in the course of historical development, are already things of the past. But this accomplished, the *organic* chemical industry of this country will commence to flourish. It will be found that the only way that leads to success in chemical manufactures is a combination of science and technics, the two branches of which eminent representatives are to-day assembled here, men who in their spheres have done so much already for the advancement of industries. It will be found that technical progress in this industry can only be secured on the basis of purely scientific research, and to the man who first recognized this fact and taught it to the world, to our great fellow countryman, Justus von Liebig, not only the German, but also the great American, nation, nay the whole world, owes eternal gratitude.

THE CONSERVATION OF ENERGY IN THOSE OF ADVANCING YEARS. III.

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How to Postpone the Degenerative Effects of Old Age.

A REVIEW of the foregoing phenomena of advancing years points clearly to the line upon which these may be in part controlled or delayed. It is not to be expected that we can secure the cooperation of most, or indeed many, people in pursuing preventive measures. If that were possible, and when it is possible, great things could be accomplished. However, certain principles obtain here which should be outlined so that whosoever may see fit to do so can follow these suggestions to their advantage. It will be found that the evidence of those who have studied this subject most carefully shows that normal bodily exercises are not to be forbidden, but rather encouraged. *Per contra*, if bodily activities are not pursued there must inevitably follow much more rapid retrograde changes in all the tissues. In respect to the diet it is universally admitted that after middle life the amount of food taken should be less than before that time and the changes in diet should be rather to use less of the structure-forming materials, though not always to exclude them. Again there should be used relatively little, indeed as little as possible, of stimulating articles of food, which make more for acceptability than necessity. In short, the simple rule should be observed of eating no more than a perfectly normal appetite craves, and as little as possible of those things taken because they are agreeable. As the period of old age is reached, by which is meant about seventy years, the regimen should be markedly simplified and always taken with the greatest deliberation. A general rule is recognized to obtain in most cases, that the more nearly the diet is reduced to bread and milk and fruits the longer will the person live and enjoy good health. It must be borne in mind, however, that exceptions will occur, and where the strength is being rapidly lost from any cause it is wise to increase the variety and encourage food taking until the strength is restored to the normal for the age reached. The digestive processes, as well as all the processes, are slower in advancing years.

Some persons can get along best with long intervals between feeding; others, the majority, do better by taking small amounts of food at short intervals. The evacuations appear lacking in activity and must be encouraged by rational measures, but not forced by purgative or strongly diuretic drugs. This is best met by suitable articles of

diet, bulky and yet not calculated to produce fermentative changes. Such qualities are found in fruits, nuts, cereal compounds and salads. Probably the best drink is buttermilk, which seems to have a salutary effect on the action of both the bowels and the kidneys. Next comes koumyss or zoolak, upon which some elderly folk have been known to subsist almost entirely for years. It is easily made at home and can be thus supplied fresh and sound and is within the reach of all, poor as well as rich. Of the cereals, Indian meal is in some respects the best, in the form of either bread or porridge. Overmuch yeast bread is objectionable, disturbing digestion and encouraging rigidities. The question of the red meats must be studied with regard to the peculiarities of the individual, but is needed very little, usually not at all. Of fluids, these are best taken in abundance, but where the heart is weak it is not wise to take them freely before exercise, as at this time they throw a perilous strain on the cardiac structures. Medicated waters are oftentimes useful, but the less inorganic drugs enter the system the better. The habit of constantly using lithia salts, exerting as they do a certain form of irritation, is to be condemned. If arteriosclerosis is present the vaso-dilator drugs are useful, especially in the forms of natural mineral waters; aconite suits many better than nitrites.

The care of the skin is of paramount importance, and the first desideratum is to employ systematic and thorough rubbing and brushing of the surface from head to heel. The flesh brush or mitten made of coarse toweling, used by the patient for half an hour at a time night and morning, serves many admirable ends and is better than too much bathing. A good plan is for the patient before rising to employ this skin stimulus and mild exercise thoroughly while in the recumbent position; if preferred and he is strong enough it is better done while sitting. The skin of old age tends to become harsh, rigid and dry, and after this effleurage it is well to rub into the body a certain amount of some oil, and it will be found that the skin will take up thus sometimes an enormous quantity. Olive oil or cocoa butter is perhaps best, but preparations containing lanolin are excellent, especially if it is desired to increase the weight and aid accumulations of fat. Sometimes crude petroleum is found useful where stimulation of the surface is required. If the skin be hypersensitive, thought must be given and changes advised in these procedures until the skin becomes inured to a suitable amount of mechanical stimulus. Old people are sensitive to cold because their surface resistance is lowered and their heat-producing powers are waning. The tendency shown by many to stay indoors and keep themselves overprotected and over-clothed is a grave error. This habit should be overcome gradually but firmly, and the patient should be in the open air as much as possible, the clothing used being sufficient, but never too much.

This is particularly true of underwear, which should be light and porous, preferably linen next to the skin, which can be supplemented by extra woolen underwear placed over this to vary with the conditions of the temperature. Outings are essential to encourage free oxygenation through the lungs and the skin. Chill of surface is much more likely to follow exertion where too much or too heavy underwear is used, and the results are far more serious than if there is too little. If the skin be leaky, becoming readily moist on exertion, excessive precaution must be used lest secondary chill follow. If the underwear is made damp by exercise, it is important to change this as soon as possible and whenever it is produced. Above all the foot gear should be frequently changed to secure airing of these over-clothed members.

The most important specific recommendations I wish to offer for the postponement of the degenerative effects of age and for the recovery of so much of the normal vigor as is possible in each have to do with the forms and qualities of the exercises. As has been shown, the tendency of the tissues in advancing age is toward a steady and irretrievable hardening or stiffening or loss of elasticity, due to normal or abnormal increase in the connective tissue. The results of these changes are seen not only in the rigidity of the spinal column and ligaments, the skin, the muscle sheaths, the structures of the blood vessels, the connective tissue framework of the great organs, etc., which are obvious enough, but the really disastrous effects are those brought about by this xerosis upon the organs concerned in the processes of nutrition and of the special senses. This point I do not see brought out in any literature which has met my eye. Let me illustrate this. We have, as age creeps on, a loss in cellular activity in the functions of the special senses, well shown for example in dimness of vision, loss of hearing and slowness of cerebration. Much of this is inevitable and must continue. Some of this, however, can be delayed almost indefinitely. It will be observed that the tissues about the neck of an old person exhibit conspicuous loss of elasticity, so much that oftentimes dense rigidities are present, especially marked in the nuchal region.

I have been surprised and gratified to find that regulated movements of the neck and upper truncal muscles, employed for the purpose of accomplishing something else, resulted in a conspicuous improvement in hearing, in vision, in cerebration and, as a consequence of a betterment in cerebral circulation, also in sleep. Following this thought I have repeatedly been able to promise, and fulfil the promise, that an individual who had suffered impairment in these particulars should enjoy distinct improvement in the function of sense organs by employing regulated movements.

What is true of these structures is equally true of the abdominal viscera. A large proportion of the digestive disturbances, even of those in earlier middle life, are due to a relaxation in the supporting tissues

of the great organs in the abdomen. It is estimated that dilatation, and letting down of the stomach, will be found in sixty per cent. of all adult persons. Oftentimes there are no symptoms indicating this, but when present they point toward a series of disturbances resulting from loss of muscular quality in the stomach itself. In those whose abdominal walls are feeble the organs have a tendency to sag and droop. This produces a series of alterations in the relationships of the organs and particularly of the blood vessels and structures concerned in their function. In the case of the kidneys, whose support is largely through the vessels which enter and leave them, and whose shape is so nearly spherical that they move readily, the suspensory tissues are not seldom twisted, thus shutting off the passage of waste material and interfering with the action of the nerves to the extent sometimes of causing pain and suppression of the function. In females this tendency to ptosis falls seriously upon the genito-urinary cycle, hence the uterus and ovaries are thrown out of their normal adjustments. In women who have borne children the abdominal parietes have all suffered more or less overstretching, and the slackening of these supporting tissues works mischief and discomfort. In some men, too, this is experienced. It becomes especially conspicuous where faulty attitudes are added to the structural defect. I have elsewhere expressed my opinions more fully on this and offered suggestions for relief (*Phila. Medical Journal,* January 10, 1903). These visceral ptoses are recognized as of large significance and their remedy is a matter of increasing importance. It can be seen at a glance that misadjustments of the abdominal organs require attention, sometimes to a very pronounced degree. The first means of relief sought by women is by the use of various forms of the corset. This garment is so universally used that we are compelled to accept it as a necessity, although I am of the opinion that we could get along very well without it if it were possible to bring women to believe so. However, the main thing is to induce women to use those corsets which will do the least harm. A certain amount of harm inevitably must follow the use of a needless artificial support. The walls of the abdomen should be competent to support the contained viscera. Where these walls are notably defective they should be supported artificially only until they can be trained to do the work adequately for which they were constructed. It is an axiom that all artificial support is merely for the purpose of conserving function until the tissues can be brought back to the normal. The first thing to be acquired in getting rid of these defects is to teach the person to stand correctly and continue to maintain proper attitudes under all circumstances. Wherever there is a stooping position maintained without effort at holding the abdominal organs in place voluntarily, there is a tendency for the abdominal viscera to pour out over the brim of the pelvis, which is thus necessarily in a slanting position.

If the neck-bones are held vertically, the ribs well lifted, and a moderate degree of tension exerted upon the abdominal walls, the viscera will rest upon, and within, the confines of the pelvis, and this position should be learned and practised; nor is it at all difficult if the attention is directed that way and some little familiarity acquired in maintaining the correct position. The body can not be held in normal attitudes unless the skeletal muscles are in fairly good tone. Most of these effects can be secured by a skillful use of breathing exercises.

It will be obvious to any one that those persons who habitually maintain an erect position in standing or sitting are stronger than those who stoop or slouch. It may be said that many of the last are perfectly well and strong, and it must be replied that they are not as well as and as strong as they should be, and further that their abdominal tissues are in perpetual danger, because an organ, or part of the body, which stands outside of its normal lines of adjustment comes closely to being in the position of a foreign body, and can not be so well protected by the central nervous control mechanism. Again, the position of the organs in the thorax are in less danger than those of the abdomen, because they have a well-constructed box to dwell in, but nevertheless they too are subjected to a good many perils if out of alignment. A person who stoops and allows the shoulders to sag down and forward and the ribs to fall back toward the spine, shortens the anteroposterior diameter of the thorax anywhere from two to five inches. It needs little demonstration to show that the lungs, heart, great vessels and other important structures in the thorax can not live, and move and have their proper being under such circumstances. Not only so, but prompt and adequate attention to these conditions results in not only improving the general health, but goes far toward maintaining symmetric functional action and the postponement of senile changes in the connective tissue.

In short, all these facts are rehearsed to give prominence to the conclusion, which seems to me inevitable, and abundantly demonstrated by data in my experience, that attention to proper attitudes, involving economies in interorganic relationships, is the one fundamental factor in postponing senile changes. The physiologic reason for urging care and persistence in retaining elasticity of tissues is to be found in the fact that sclerotic changes and faulty attitudes combine to interfere with peripheral vascular competence as well as peripheral innervation. To recur for a moment to the illustration used above, of the marked improvements following increased flexibility in the tissues of the upper thorax and neck, it is my opinion that this is to be brought about by thus promoting and encouraging fuller circulatory interchanges, especially of the lymphatic channels.

I am also of the opinion that arteriosclerosis is thus postponed, and sometimes prevented, hence the same principles hold good throughout the entire economy. It may not be necessary to develop this thought further, but to assume the truth of what I regard as an original observation, that systematized effort at elasticizing of the tissues is the basis upon which sclerotic changes generally can be delayed and made less. The means by which this result is to be attained consist chiefly in employing movements taught by a skillful person, and this should be the physician himself, assisted, it may be, by an expert trained by him to pursue the work in detail. Free exercises in the open air, proportional to the capacities of the individual, are of the greatest importance and should be regulated with the same care and supervised with the same conscientiousness as any other medical measures. Among those of the utmost importance are prescribed movements which differ in degree at least from the ordinarily employed remedial movements whose main object is to improve muscular tone, and which are largely flexor for the arms, with only a moderate degree of extensor activities. For older people there should be a steadily increasing attention to the extensors and less action demanded of the flexors. First these should be passive in the form of stretchings, rotations and torsions carefully and deliberately applied to the limbs and trunk and the neck. These should be moderately supplemented at first by voluntary movements in the same direction. Later, as vigor improves, and the heart action is strengthened, and the blood vessels recognized to be better able to stand the increased vascular tension induced by exercise,* these may be employed more forcefully until, by and by, the patient, even when well advanced in years, can endure a degree of muscular work which is surprising. Not only so, but this results in a feeling of well-marked enjoyment, not only of the restoration of sensations due to the improved circulation and in increased resistance to temperature changes, but in the procedures themselves which come to be distinctly relished.

In this connection let me say a word about the senile heart. It is generally accepted in a fatalistic sort of way that old people are unfit for activities, that they must do as they are inclined to do, little or nothing but exist, like vegetables. My own experiences and convictions in this particular seem fortified by the best authorities consulted. In my opinion the disinclination to movement and effort is rather the result of under-oxygenation, a habit, or other conditions which make for what one may almost call senile laziness, than an instinctive economic impulse. It is obvious that the healthier and happier old people are those who are reasonably active. My experience justifies the conviction that where activities have been encouraged, always with full

* This increased vascular tension as Oliver and others have shown, is quickly followed by a fall. Hence the most salutary means of lowering tension is by exercise to the point of skin relaxation—sweating.

estimation of the limiting conditions present, improvement results. This is true, and demonstrated to be so, under circumstances which would be considered prohibitive; for instance, where there have been observed those phenomena supposed to indicate threatened apoplexy, however that term be interpreted. I have had a number of cases under observation for many years where I was originally consulted for a train of symptoms which pointed toward cerebral changes such as vertigo, lapse of memory, sensory disturbances in hearing and in sight, formications, paresthesias, periods of brief unconsciousness, etc., in people of seventy years or more. Ordinarily the treatment advised for such conditions would be to reduce the individual to live the life of a hothouse plant. I have found in this contingency great practical advantage in attending to the cutaneous elimination, especially by frictions, oilings, massage, passive movements carried on to full stretchings as described above, and gradual increments of stretching exercises, forceful extensions and finally free movements and open-air life. Some of the individuals are now past eighty, strong and well. Even where there are found to be alterations in the kidneys, sometimes albumen, casts and sugar, the encouragement of the peripheral vascular stimulus was followed by the happiest results. Above all, in the cardiac arhythmias attention to the skin and regulated movements reduce these and sometimes cause them to disappear.

The pulse in old people, as has been said, is quicker than in middle life. The average of those cases reported by Humphrey, all of them over eighty years of age, were for men seventy-three per minute, and women seventy-eight, and the average respiration was seventeen. The proportion of regular to irregular pulse was four to one. I find irregularity in the pulse more common, indeed, it is generally present more or less even in the healthiest. Humphrey also found in the majority of old persons examined, little or no change in the arterial system. Clifford Allbut makes the assertion that in many cases of extreme age no evidence of arteriosclerosis is to be found. One of the oft-recurring phenomena of old age is edema due to the loss of vascular tone and defective lymph circulation. This condition would be much less frequent if the tissues, especially the larger muscles, were kept in a condition of elasticity, thus relieving direct pressure and occlusion of the contained avenues of circulation.

The exhaustion after fatigue is not well recovered from in the aged, and hence it is not permissible to maintain protracted activities; these should be supplemented by definite periods of rest, and if the heart be not strong this should be taken lying down, but this is no reason to encourage complete inaction. Again, the change characteristic of the bones of the aged, their loss of weight due to diminution in size, the walls of the shaft becoming thinned throughout from within, especially towards the ends of the bones, as at the head of the femur, forbids strong

muscular exertion such as lifting. Nor should activities be sudden and severe, otherwise the danger of a false step and a fall may result in a shock or fracture or both. Nor is it important nor desirable that the muscles should be kept at their full strength, even if it were possible. The quality of musculature is mainly desirable for the purpose of oxygenation and to maintain full skin activity, freedom from stiffness and the consequent compression upon the blood vessels and nerves. In short, the component parts of the machine in healthy old age are slowly and equally weakened. They fail to respond to calls, the centers giving out less early than the outer parts, but these same centers should be maintained at their best for so long as it is possible. Finally the wheels of the machine stop. This slow decline is really a beautiful spectacle and requires the sheltering influences of civilization and sympathetic care. In the state of primitive society man died even as the animals and birds die, the one by the hand of the stronger. When assailed by sickness or age, death came swiftly from one or another agency of nature, either from animal or man. In civilization much vigor can be conserved indefinitely, or at least to well toward the century mark, provided the aged persons exercise judgment in the manner of life lived; and if cut off before a reasonable time the fault lies within themselves or their circumstances. In this slower decline it is more possible for disease and decay to become manifest, but even here prevention is a large possibility. If the heart, or the digestive organs, shall be kept disproportionately vigorous they will overload and press the other organs, and one of these, the weaker one, gives way.

The use of inorganic drugs has little place in relieving the grave disorders of the old. When these are found in the form of the natural mineral waters they have, since time immemorial, been held in high esteem for definite and indisputable good effects, the nature of which has never been satisfactorily explained. Modern studies on the physiology of the blood, especially of the serum, helps to account for this. Recently Trunecek, of Prague, has announced a method of treating the phenomena of arteriosclerosis which has been not only most successful, but suggestive, and seems to me to throw light on the value of mineral waters which will prove a rich field for research. His thesis is that certain salts can be introduced into the blood current which shall aid in dissolving the calcium phosphate found in the structure of the sclerosed vessels. Hence he adopted the plan of throwing into the circulation direct, by hypodermoclysis or intravenously, a strong solution of sodium phosphate and magnesium phosphate which are found normally in blood serum but only in minute quantities. His followers have obtained gratifying results, and many modifications are made of his original solution. Leopold Levi used this by the bowel and the mouth and it was found that the latter gave just as good effects.

Under this treatment the usual discomforts and evidences of dis-

turbed circulation, such as dyspnea, asthma, vertigo, angina pectoris and prostration, rapidly lessened or disappeared far better than by the use of aconite, iodides and nitrites, although it occasionally transpired that when these last were also used the progress was more satisfactory.

It occurred to me to review the analysis of the various mineral waters, and I was surprised to find how many of them exhibited likewise many of these ingredients, in varying proportions, along with one or other factor to which the virtue of the water was chiefly attributed. Hitherto these factitious items have been regarded as indifferent or to them have been attributed various hypothetic or conjectural virtues. We have been long recognizing that the use of certain of the alkaline waters lessened the acidity of the urine and presumably of the blood, and the laity have been taught, partly by the profession but chiefly by the manufacturing chemists and the public press, that if ever the demon of uric acid can be laid, by the ingestion of enough of lithia salts or of some of the new and wonderful substances the special product of the great laboratories, their imperiled lives can be saved and most ills removed. The reaction against this notion has set in, but the fad remains, and will prevail long among the people, and the non-reading of the profession, that alkalies are helpful in a vast variety of vague states accompanied by the output of the uric acid in the urine common to about one fifth of the community. The real point of effort should be the restoration of the functional activity of the liver, which has to do with the conversion of ammonium cyanate, uric acid and other end products into urea. This is to be accomplished in a number of ways, the basis of which is to bring about bettered circulation in the liver and more complete functional power. For this, as well as to accomplish many other functional betterments, no single measure is comparable to regulated, deep breathing exercises. Complete expulsion is even more necessary than full inspiration. The abdominal muscles can thus be made to press upon the viscera, especially the liver and great organs, aiding largely in vascular interchanges hence secretion and excretion. By this means chiefly, if not alone, bowel action is sometimes regulated, and kidney competence enhanced.

There may be, and it seems that there is, considerable efficacy in the use of natural mineral waters, which exhibit a reasonable proportion of those salts that exert a solvent action on lime salts or other adventitious substances. Drugs, however, serve a temporary purpose and, in such conditions as the discomforts arising in beginning degenerative processes of age, would seem to need an indefinite continuance. The real curative remedy and defensive measure is in aiding oxidation of the tissues by all rational means, special movements and stimulation of the vasomotor mechanism of the great eliminating organs.

THE CAUCASIAN IN BRAZIL.

By THOMAS C. DAWSON,
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CONTROL of trade routes and mineral supplies have been the two chief factors in determining the industrial and political supremacy of races and nations. It is evident that a third—the control of the food supplies from the tropics—will soon be equally vital to civilized man. The tropical zone is a great laboratory where nature's forces are manufacturing food on a tremendous scale. There the sun's vivifying rays fall in the greatest abundance, building up with a rapidity impossible in the temperate parts of the globe the elements of the air, water and soil in those complex compounds which are the essential basis of life. Leaving out of consideration the dream that inventive genius may some day devise artificial methods of employing the sun's chemical forces in directly producing food, it is certain that if he continues to multiply in his present geometrical ratio, the European must utilize the tropics.

India and the east already contain a dense population; but the negroes who inhabit tropical Africa do not begin to exhaust its potential resources, and South America, the queen of the continents from an economic standpoint, is virtually untouched. How and by whom shall these regions be occupied and developed? Three solutions are possible:

1. Races predominantly black or yellow, who shall have developed among themselves or acquired from the whites economic and political efficiency, may be the future masters of the now unoccupied parts of the tropical zone. Southern China is a proof that such an outcome is possible.

2. Colored people under the direction and government of northern nations may cultivate the soil and export the surplus. This would be something parallel to the present condition of India.

3. The whites of European descent may themselves emigrate to the tropics, crowd out or absorb the colored races, and either pure, or predominating in the resulting mixture, constitute the bulk of the population.

The last alternative is rarely taken into consideration, because it is an accepted commonplace of popular belief and scientific discussion that the white man is not fitted to the tropics—that the European

races can not live and multiply in the fertile regions near the equator. It is assumed as a self-evident truism that the blacks or colored races can better resist the climatic conditions. The statescraft of to-day, acting upon this assumption, is bending its energies to laying the foundations of an external dominion over the hot regions of the earth. Spheres of influence, not fields for emigration, are the subjects of the preoccupation of European cabinets; trade and political control are more sought than opportunities for colonization.

The popular impression as to the suitability of the tropics for white settlement rests upon two commonly observed phenomena: The places most visited by travelers, and therefore best known, are inhabited principally by colored races; the white man loses vigor when suddenly transported into winterless regions from the more vigorous climates where his ancestors have been living for unnumbered generations. Besides, the white emigrant usually dislikes the social, industrial and political surroundings, becomes discouraged, and in most cases returns strongly prepossessed against the tropics.

As to permanent powers of reproduction and survival, the existing predominance of colored races and the ill health and dissatisfaction of newly arrived whites only create a presumption—they do not conclusively prove anything. The negroes may predominate in Jamaica, because black immigration to that island was vastly more numerous than white, and not because the whites that did go there died out. The Caucasian newly arrived in Rio de Janeiro is susceptible to yellow fever, but his children born in Brazil may not be less immune than the offspring of black slaves.

Many things I have seen during a long residence in tropical Brazil and in journeys through the states of that republic and of neighboring countries have led me to doubt the correctness of the general impression. Personal observations unaided by adequate statistics are notoriously untrustworthy, and one should be slow in drawing conclusions from them. However, no one can long travel and reside in Brazil without noticing that white families are large and their children healthy. A large proportion can trace their descent to colonial times. Whites are preferred to negroes, mulattoes or Indians as laborers on the railroads and coffee plantations, not only because they are more intelligent, but because they are stronger, healthier and more energetic. The white may be more susceptible to certain climatic diseases, but the negro is less able to resist others, and is decimated by such communicable maladies as smallpox and consumption. The white eats more and better food, lives more hygienically and protects himself more effectually against the weather.

A study of the population statistics of Brazil leads to some surprising conclusions. The returns of marriages and births show that

the whites are more fecund, and the successive censuses appear to prove that during the three and a half centuries which have elapsed since the settlement of the country, the comparatively few white immigrants have multiplied at a far more rapid ratio than the multitudes of negroes brought over from Africa, or the Indian aborigines.

In 1890 an enumeration was made of the married couples in the city of Rio de Janeiro; the race and color of each partner was ascertained and reported, and also the number of children born of each marriage. The average number of children in families where both parents were white is given as 3.507, while the black families produced only 2.987, and the intermarriages of blacks and mulattoes, 2.908. Of all the children 75.2 per cent. were the offspring of parents who were both white, leaving 24.8 per cent. for children of mixed or colored blood. The total white population was returned as 62.7 per cent. and of the other races at 37.3. Taking the four races separately, the whites, numbering 62.7 per cent. of the total population, took part in only 6.9 per cent. of the marriages and only 6.1 per cent. of the children had one or both parents black. The Indians were 3.4 of the population and furnished 2.4 per cent. of the marriages and children. Those reported as mulattoes composed 21.6 per cent. of the population, but took part in only 13.9 per cent. of the marriages, which produced 13.2 per cent. of the children. Irregular unions producing children are reported as marriages, and therefore the differences indicated above can not be explained by assuming that negroes, mulattoes and Indians live in concubinage more than the whites. A considerable number of those reported as 'white' have a small amount of negro or Indian blood in their veins, but this fact does not affect the conclusion that fecundity increases with the predominance of white descent.

Leaving out the mixed marriages, the superior fecundity of the whites is still more apparent. Of the children of unions where both parties belonged to the same race, 81.6 were white; 11, mulatto; 5.3, negro, and 2.1, Indian, while the respective percentages of total population were: white, 62.7; mulatto, 21.6; negro, 12.3, and Indian, 3.4.

It is therefore clear that even in Rio, a seacoast city whose climate is reputed particularly fatal to Europeans, whites now show a greater propensity to marriage than the black or mixed races, and that their unions are more prolific. Comparative mortality statistics are not available, but it is probable that the acclimatized whites are longer lived than the other components of the population, and that this has cooperated with their superior fecundity in bringing about a more rapid increase as compared with other races. The various censuses of the city of Rio de Janeiro taken in the last hundred years show the result that was to be expected from the above figures. The percentage of whites increased from 45 per cent. in 1799 to 55 per cent. in 1872,

and 62.7 in 1890. That of the negroes fell from 54 to 14.5 and then to 12.3 per cent. in spite of the excess of negro over white immigration, which continued until the suppression of the slave trade in 1854. Since that date European immigration has been great. However, the proportion of whites of foreign birth decreased from 34 per cent. in 1872 to 30 per cent. in 1890. Native whites numbered 34 per cent. in 1872 and 51.6 in 1890, while the blacks fell from 21.7 to 16.3.

The movement of population from Rio to and from the surrounding country undoubtedly affects the relative proportions of whites and blacks. This element of uncertainty does not exist when the population of the country as a whole is studied, and the successive general censuses of Brazil afford a better basis for calculation.

Brazil was settled in the middle of the sixteenth century by the Portuguese—a people formed of the mixture of many nations, all of them, however, of pure Caucasian descent and the vast majority belonging to the Mediterranean race. The country was found inhabited by red Indians, who closely resembled the North American aborigines, and who readily submitted to white domination. The reports of the Jesuit missionaries and parish returns show that the process of incorporating them with the religious, political and industrial framework of the colony was begun immediately and continued for nearly a century and a half. About five thousand Indians were so civilized and incorporated.

Almost simultaneously with the original white settlement the importation of negro slaves from the near-by African continent began, and it was continued on a large and increasing scale for three centuries. By the end of the eighteenth century the arrivals had reached twenty thousand yearly. It is estimated that about two millions of negroes were imported into Brazil during the colonial period.

White immigration was surprisingly small. Portuguese policy did not aim at erecting a new Portugal across the sea, but at making a profit out of the region by the labor of Indian and negro slaves. No foreign whites were allowed to enter Brazil, and it was difficult even for a Portuguese citizen to obtain the required passport. About twenty thousand emigrated to central Brazil with the early expeditions by the colonial proprietors and the government. In the beginning of the eighteenth century several thousand Azoreans went to northern Brazil. A century later the discovery of gold in Minas Geraes stimulated a rush estimated at twenty or thirty thousand. In the middle of the eighteenth century there was a considerable influx of Azoreans into extreme southern Brazil. With these exceptions whites came singly or in small bodies, being mostly officials, soldiers, proprietors coming to take possession of huge land-grants from the crown, mer-

chants and a few convicts. The total white immigration for the whole colonial period was about two hundred thousand.

No census was taken in 1807, but partial enumerations made shortly before indicate that the population of Brazil was then composed approximately of 900,000 whites or very light mulattoes; 2,000,000 negroes; 400,000 mulattoes, and 260,000 civilized Indians. In 1808 the mother country was overrun by Napoleon's armies, and the Portuguese king fled for refuge to Brazil, accompanied by thousands of office-holders and soldiers and most of the court. Fifteen thousand persons crowded the ships which carried John VI. out of the Tagus. His first act on arriving in Brazil was to open its commerce to all the world, and thenceforward immigration was unrestricted. White arrivals from 1808 to 1817 were 40,000, and those of negroes, 200,000.

The census taken in the latter year gives the white population at 1,043,000; negroes, 2,350,000; mulattoes, 426,500, and Indians, 259,500. The whites had constituted only 8 per cent. of the original components of the population, but now numbered 28 per cent., while the negroes had fallen from 74 to 62 per cent. and the Indians from 18 to 7.

In the fifty-five succeeding years until 1872, 813,000 blacks were imported and 432,000 white immigrants arrived from Europe. The census taken in the latter year gives the white population as 3,787,289, and that of negroes as 1,959,452. Therefore the 672,000 whites who had come to Brazil up to that date had increased 562 per cent., while the 3,013,000 negroes had decreased to 65 per cent. of their original numbers. The civilized Indians surviving were only half as numerous as their ancestors.

In making a calculation of the total proportions of the three races in the total population of the country there are two uncertain elements which must be taken into consideration. In the census of 1872, 3,750,000 persons were returned as mulattoes or 'caboclos' (white and Indian, or negro and Indian), and no data is given as to what proportion of the three bloods entered into the mixture. Some of those returned as 'whites' were in fact light mulattoes or 'caboclos.' The latter fact would certainly tend to increase the apparent ratio, and it is also probable that the proportion of white blood in those returned as mulattoes is smaller than the proportion of negro and Indian blood. Personal observations indicate that the non-Caucasian element in those returned as 'white' is less than one fourth, and that about two thirds of the ancestors of the mulattoes are negroes or Indian—principally the former. Assuming these ratios in default of statistics on the subject, the population of Brazil in 1872 was 42 per cent. white, 53 per cent. negro and 5 per cent. Indian, while the percentages in the original immigrants were, respectively, 16, 72 and 12.

European immigration from 1872 to 1889 inclusive amounted to

611,000, while the negro arrivals had ceased almost entirely with the abolition of the slave trade. The census of 1890 does not give race numbers as to many localities, but estimating these on the basis of the sections where the relative proportions were ascertained, the percentage of whites is 44; of negroes, 18; of mulattoes, 35, and of Indians, 3. Dividing the total population into its race elements according to the principle already used with the figures for 1872, after making an allowance for the lessening proportion of dark blood among the reported 'whites,' we find that in 1890 there was 49 per cent. of white blood, 47 black and 4 Indian.

The tendency of the pure negroes to decrease in numbers is conclusively shown by the accurate statistics of the slave population kept during the existence of that institution in Brazil. In 1818 the slaves numbered 2,350,000; in 1872, 1,510,806; in 1887, adding their children born free under the gradual emancipation law of 1873, 1,183,250.

The immense extent of Brazil, the wide variations in climate, soil and altitude, the predominance of sugar culture with the employment of great gangs of slaves on large plantations in some localities, and of the cattle industry which the whites are fond of in others, and the fact that sometimes the Indians were collected into villages of their own and sometimes were enslaved and almost exterminated, have caused great differences between the various states in the relative numbers of the three races. The limits of this article do not permit a discussion of each state separately, but it would confirm the conclusions already indicated.

Even in the parts of Brazil which are the most tropical and least attractive to Europeans, and where white immigration during the last century was inappreciable, such as the non-coffee and sugar states of the central and northern coast, and the wild and remote interior included in the states of Goyaz, Minas and Matto Grosso, the whites have increased more rapidly than pure negroes or Indians. The latter tend to disappear into the mass of mixed bloods who constitute the bulk of the population. A large proportion of the Caucasians have, however, maintained themselves in direct, prolific and unmixed lines for three hundred and seventy years, and their commercial and intellectual dominance has never been threatened.

In the favored regions of the south the preponderance of the whites is enormous and is rapidly increasing. On the coffee plantations of Sao Paulo, where the negro slave formerly did all the work, he has been completely displaced by the immigrant from Europe. The negroes and mulattoes have little chance of intermarrying with the whites; their unions among themselves produce a small number of children, and they show little providence in forming and taking care of families. They do not have, as do their contemporaries in the

United States, the stimulus of a comparatively rigorous climate, and the examples of white neighbors organized into a complex and highly competitive industrial civilization. The reserve of foresight, energy and ambition which the white Brazilian has inherited from his ancestors stands him in good stead in the easy and enervating surroundings, while the negro will only work when he is obliged to.

The race which will inherit the fertile and salubrious plains and plateaux stretching north from the Argentine border to the lowlands of the Amazon will probably be of Caucasian origin and descent, although its characteristics may have become much modified in fitting its new surroundings. The Azorean hoes his little patch of ground with the painstaking industry of the Norman peasant, but his gaucho descendant in Rio Grande neglects agriculture for riding after cattle. A capacity for indolence may perhaps be one of the conditions of survival in tropical climates, and the future master of these regions will possibly possess oriental characteristics, and may lose some qualities he inherits from his immediate ancestors, the restless Latins, Celts and Teutons of western Europe.

So far as it has gone, Brazil's experience tends to prove that the white man has the adaptability, vitality and fecundity to ensure his preponderance in the tropics as well as in the temperate zone, and that the other races will exist there upon his sufferance.

THE AIR OF THE LURAY CAVERNS.

By GUY L. HUNNER, M.D.,
THE JOHNS HOPKINS UNIVERSITY MEDICAL SCHOOL.

AT Luray, Page County, Virginia, is located a health resort which represents an idea unique in hospital or sanitarium construction. The dwellers in Limair may keep their doors and windows closed summer and winter, and still breathe air as pure as that of the mountain side.

My acquaintance with this institution began in the fall of 1901, when making a vacation drive through the Shenandoah country. After a ramble through the Luray Caverns, our party was shown through the sanitarium and treated to the novel experience of living in the caverns' air, while enjoying a full measure of light and sunshine.

Limair has an elevation of about one thousand feet above the sea level. It stands on a hill about two hundred feet above the neighboring water courses, and commands a magnificent view of the Page Valley with the enclosing mountain ranges—the Blue Ridge to the east and Massanutten range to the west. These mountains are from three thousand to four thousand feet high, and as seen from the elevation in the center of the valley they present a panorama of never-failing interest. The Page Valley is said to enjoy more sunshine than can be elsewhere found in the United States east of the Rocky Mountains. A pine forest of about one hundred and forty acres which covers the Luray Caverns hill affords beautiful walks and drives, and is not the least of the attractive features of the place, when considered as a health resort.

Mr. T. C. Northcott, builder and proprietor of Limair, is a heating and ventilating engineer of twenty years' experience, and he has devoted many years to the problem of establishing an institution that would combine the advantages of sunlight and beautiful surroundings with an air supply at once voluminous and pure. After investigating the caves of New York, Ohio and Virginia he secured building and park privileges over the Luray Caverns as a site comprising the greatest number of healthful and attractive features. A reference to the photographs (Figs. 2 and 3) will give an idea of how well the site has been chosen. The drawing (Fig. 1) explains the methods of air supply and ventilation, but only a visit to the institution will demonstrate how completely the theories of the engineer are being worked out in practical results.

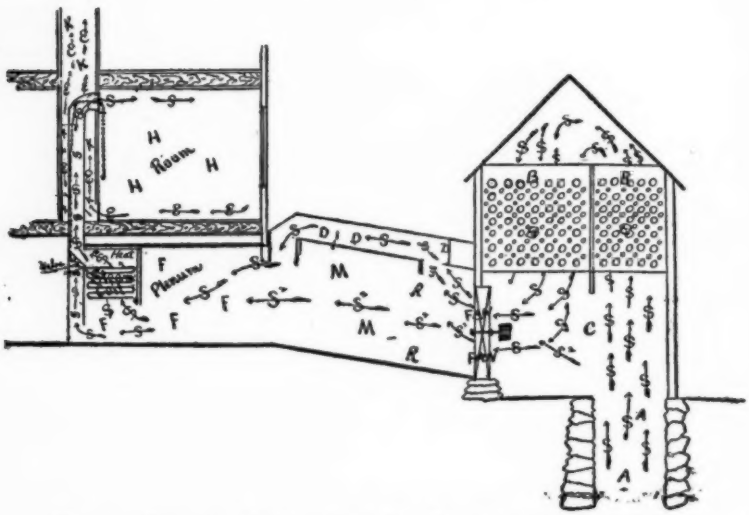


FIG. 1. SHOWING METHODS OF AIR SUPPLY AND VENTILATION.

The fan, shown in drawing, is run by steam-engine (not shown) and draws the air upward, from the great chambers of the caverns, through the shaft *A*. By opening door *C*, also door *R*, the air can be forced through corridor *M*, directly to plenum *F*, as indicated by arrows marked *S*², and distributed through the rooms without passing through condenser. With door *C* closed the whole volume of air is drawn through condenser *B* before coming to the fan. Passing through the fan (door in partition at *R* being closed), the air passes through an auxiliary condenser *D* to plenum *F*, whence it is forced by pressure of the fan into all rooms. The air from plenum is forced through a heat chamber, over steam coil, in cold weather, thence through opening into the air supply pipe *G* and discharged into room *H* through a register just below ceiling of room. If room becomes too warm, the volume of *warm* air flowing in pipe *G* may be reduced or entirely stopped, by pulling cord or chain suspended from the inflow register in room, thus moving valve in pipe *G*. The movement of this valve permits as much *cool* air to rise through a lower opening, as warm air is shut off by closing the opening from the coil, or heat chamber. Process last described may be traced by arrows marked *S*. The outflow of air from rooms may be traced by arrows marked *E*. Air is forced from room *H* into vertical duct *K*, which is continued to top of building permitting air to escape outdoors. *The air passes into, through and out of the rooms in volume equal to the filling of each room in the building every five minutes continuously.* In the summer there is, of course, no heat in the steam coils. The air drawn from the caverns being about 54 degrees, when forced into the building, cools the rooms to any degree comfort may demand, however intense the heat prevailing outside.

At my first visit, in the fall of 1901, I saw demonstrated the remarkable volume in which the air enters and leaves each room without creating appreciable draughts, and the fact that the air is practically free from atmospheric dust. Tyndall ('Lectures on Dust and Disease') has shown that if we darken the ordinary room and allow a streak of sunlight to enter, the condition of the atmosphere revealed is such that

we can not without repugnance step into the illuminated area and breathe. Such an experiment in a room in Limair reveals scarcely a particle of dust floating in the air; *i. e.,* the air is optically pure. Noting this fact, I became interested in the bacteriologic condition, and determined to visit Luray again, supplied with culture media and sterile plates.

In December, 1902, fitted out with five dozen sterile plates and six dozen tubes of agar-agar, I spent four days at Luray studying the bacteriologic conditions in the caverns, sanitarium, out of doors, and in neighboring homes. My plates were prepared by being wrapped in separate paper covers, sterilized in dry heat and transferred to a box still wrapped in their paper covers. The agar-agar was in separate tubes stoppered as usual with cotton plugs. Each morning before starting in quest of bacteria the required number of fresh plates were prepared. That my technic was entirely satisfactory was demonstrated by setting a closed control plate at each place where other plates were exposed. The readings from the plates were made after incubation for twenty-four hours at 85 degrees F. On the first day the exposures and results were as follows:

1. In the caverns: Three plates in Vegetable Garden, 50 yards from entrance; plates exposed five minutes and one hour and the control plate were all negative.

Three plates at Crystal Spring, 100 yards from entrance; on plate exposed five minutes, two colonies; plate exposed 50 minutes, negative; the control plate, negative.

Three plates at Skeleton Gorge, 200 yards from entrance; 5 minutes, 35 minutes, and control, all negative.

Three plates at Cathedral Room, 300 yards from entrance; 5 minutes, 30 minutes, and control, all negative.

2. In the air passage between the cave and the house (see Fig. 1) four plates were exposed for one half hour as follows: Plate 1, at the mouth of the air shaft coming from the caverns, *A;* plate 2, in the beginning of the long auxiliary condenser, *D,* just beyond the fan; plate 3, at the other end of the auxiliary condenser; plate 4, on the floor of the plenum, where the air rushes down from the condenser. On none of these plates was there any growth.

3. In the sanitarium three plates were exposed for respectively 5, 20 and 60 minutes in each of three rooms, viz., the library on the first floor; a guest chamber on the second floor, not used for the previous week; and in a bedroom on the second floor, in constant use. The morning work had been done in this latter room one hour before my plates were placed on the bed. One colony on the five-minute plate, and three colonies on the 60-minute plate in this room, and two colonies on the hour plate in the library were the only results from these nine plates.

On the evening after my first day's work, the daughter of the household gave a party to about fifty young people of Luray, and on making my first examination of the plates, I was so astounded at the results that I immediately prepared more plates, thinking that enough dust and dirt would have been left in the house on the previous evening materially to alter results. I was even more surprised after exposure of plates for two hours in the library, reception hall and game room, to find the most contaminated plate to contain only nine colonies. This was the plate exposed on the mantle shelf immediately above a large open fireplace in the reception hall, between the hours of eleven and one o'clock noon, when the household of about six people was moving about as usual on a winter morning.

Plates were set for two hours in the caverns on the second day at the same places as on the first day. Again two colonies developed on the plate exposed near the Crystal Spring, while the other plates were negative.

For the sake of comparison, and to learn whether all houses in that vicinity contained unusually pure air, I exposed a plate in the house of a well-to-do farmer within a mile of Limair. The house was scrupulously neat and clean. The plate was exposed for one hour on a mantle-shelf back of a heating stove in the sitting room, where five or six people were passing in and out. In other words, the conditions were about the same as those under which nine colonies developed after a two-hour exposure at Limair. After 24 hours of incubation 143 colonies were visible on this one-hour plate.

In a physician's office at Luray 92 colonies were implanted in one hour. I expected to catch more bacteria in a physician's office than in a farm-house, and the difference may possibly be explained by the location of a large, open fireplace opposite the door entering from the street, thus affording a means of constant ventilation, with repeated additions of fresh air from the outside.

Outdoor exposures were made at Limair on a clear morning following a day of rain and freezing temperature. The temperature was 38 degrees and a mild wind was blowing. Four plates were exposed in the pine woods at some distance from the house, the exposures lasting from one to two hours. Three plates each showed two colonies, while the fourth had four colonies; of three unopened control plates one showed one colony. To compare the air in the city, I exposed a plate for one hour on the stone wall surrounding my back yard. The plate was exposed at 5 P.M. on a clear, bright day, the temperature being below freezing, and the wind blowing about twelve miles an hour. The previous two or three days had been clear and dry. After 36 hours' incubation at 85° F. 450 colonies had developed on the plate. A plate placed on the seat beside me in a Madison Avenue car, during

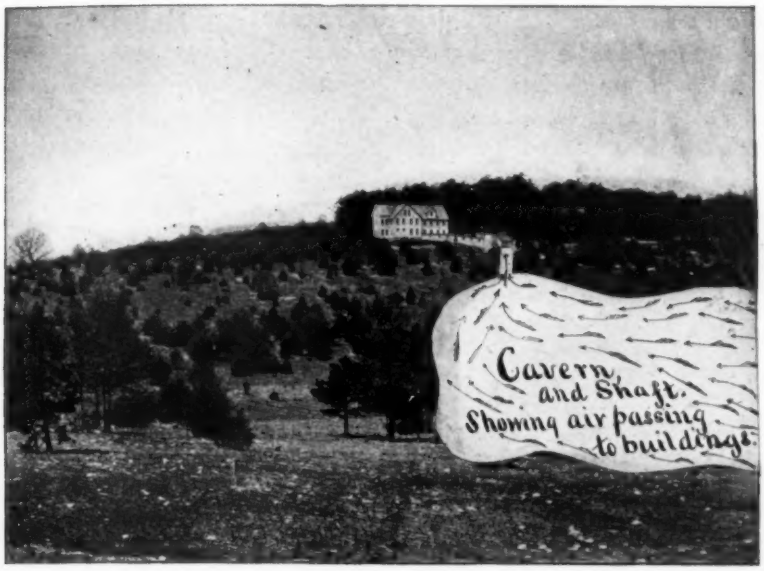


FIG. 2. LIMAIR SANITARIUM, LURAY, VIRGINIA. Notice the absence of roofed verandas. Large sun rooms occupy the south side of the sanitarium. Massanutten Mountains just visible in the distance.

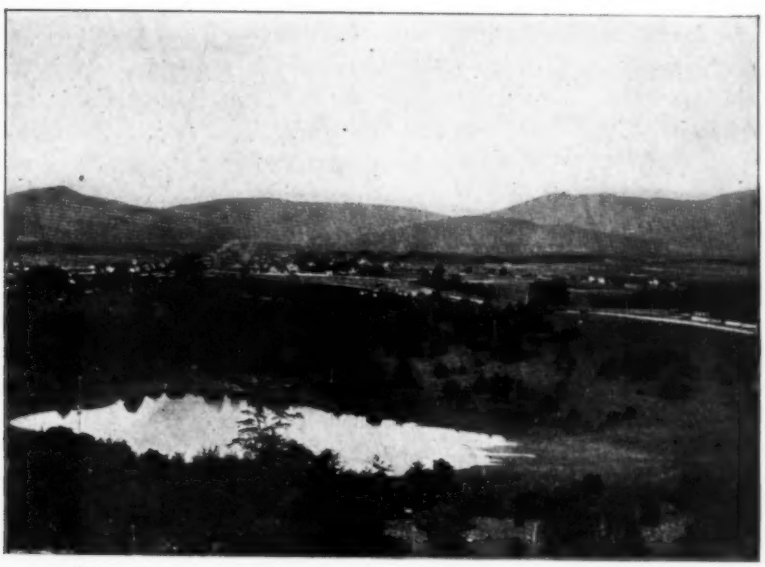


FIG. 3. VIEW FROM SUN PARLORS OF LIMAIR SANITARIUM, LURAY, VIRGINIA. Luray one mile distant. Blue Ridge Mountains beyond.

a twenty-five minute trip from Broadway to Lafayette Avenue, showed over 1,600 colonies after a thirty-six-hour incubation at 85° F. Plates exposed for one hour in the surgical and gynecologic operating rooms at the Johns Hopkins Hospital showed, respectively, 65 and 58 colonies after incubating 48 hours at 100 degrees. These comparative studies are suggestive, and the studies in the caverns and sanitarium demonstrate that with optical purity or freedom from atmospheric dust, we have air that is practically free from bacteria.

FIG. 4. SHOWING FLAG BENEATH THE CEILING CARRIED OUT HORIZONTALLY BY THE INFLOW OF CAVERN AIR. Also the flame of the candle deflected by the outflow of air from the bedroom.

But in spite of the bacteriologic purity of the air in Limair Sanitarium, I am sure many will protest against breathing the polluted, moldy emanations from a source never penetrated by the rays of the sun. I must confess this was my first impression, and the same prejudice has been expressed by many friends with whom I have conversed. But what are the facts, and what is the condition of the caverns' air? In the first place the air is not stagnant. In any part of the caverns the guide's candle, if placed on the floor or on the ledge of a wall, shows by the deflected flame a very decided current of air. Owing to the differences in temperature, there is a constant interchange of air between the caverns and the outside world. This circulation takes place through many natural filters distributed over the hillside in the form of crevices in the rock, which have become filled by porous soil. Both air and water are cleansed in passing through these earth filters. If there be any open fissures for the admission of unfiltered air, its organic particles would soon be deposited on the damp caverns' walls. The action of water passing over and causing the slow dissolution of such a vast surface of limestone can not but be

beneficial to the caverns' air. It would be trite to dwell on the advantages of lime as a purifier and disinfectant.

Again, we find no organic matter in the caverns undergoing decomposition, and have on every hand the beautiful, clean, limestone walls and draperies being corroded and reformed by the constant action of myriads of water courses (see Fig. 5). Can we arrive at any other conclusion than that here we have the purest and cleanest atmosphere that can anywhere be found?

Mr. Northcott's control of the temperature and humidity conditions is a feature over which the thoughtful visitor must grow enthusiastic. The temperature of the caverns registers from 54° to 56° F. throughout the year, and the relative humidity varies but a fraction of a per cent. from 87. In the hottest summer weather the sanitarium tem-

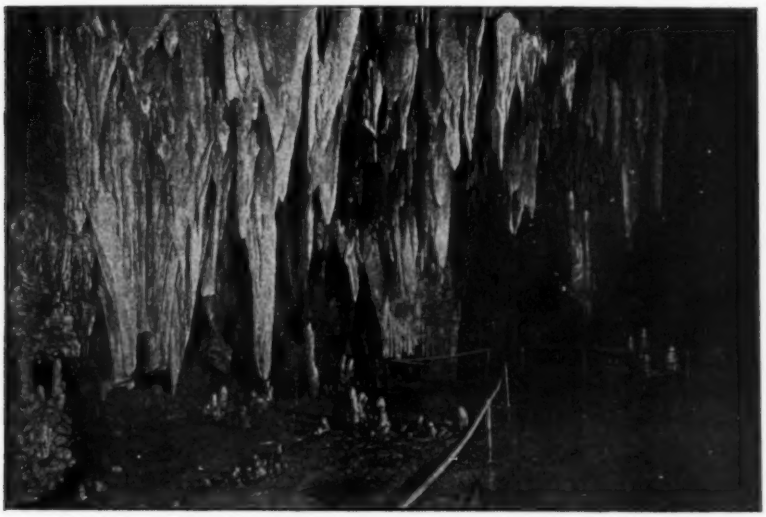


FIG. 5. SIDE VIEW OF BALL ROOM.

perature ranges from 70° to 74° F., and the relative humidity is reduced to 70 per cent. or less, merely by the expansion in volume incident to an increase in temperature from 56° to 70°. In the winter the air is easily raised in temperature from 54° to 70°, and the problem of humidity, while somewhat more complicated than in the summer, is perfectly controlled. As seen in Fig. 1, the air is sent through a boiler-like box of sheet iron (*B*) and comes in contact with a wide surface of iron tubing, the opposite surface of which is exposed to the cold air outside. This one box failing to reduce the humidity sufficiently, there was built a long sheet-iron passageway (*D*) over the summer air corridor, and by placing a closed door (*R*) the air is forced through this accessory condenser to be still further robbed of its moisture.

Dr. Wm. C. Bailey, who is doing such excellent work with consumptives at Las Vegas, N. M., informs me that the yearly average of humidity at his altitude is 40 per cent. The average at Denver is about 50 per cent. at 70 degrees temperature. When we consider the great and rapid changes of temperature at such favorable locations, and think of the wide range of relative humidity experienced even in the course of one day, we see at once that the engineer at Limair, starting with his great caverns of air of a uniform temperature, and uniform percentage of relative humidity, has a simple problem to solve in keeping the sanitarium at an equable temperature, and in what is considered the normal percentage of relative humidity. Attempts are now being made to furnish hospitals and large public buildings with these desirable conditions of a dustless, cool air, of uniform temperature and humidity; but while the problem is theoretically possible, the outside conditions are such as to make the undertaking one of such expense as to be impracticable.

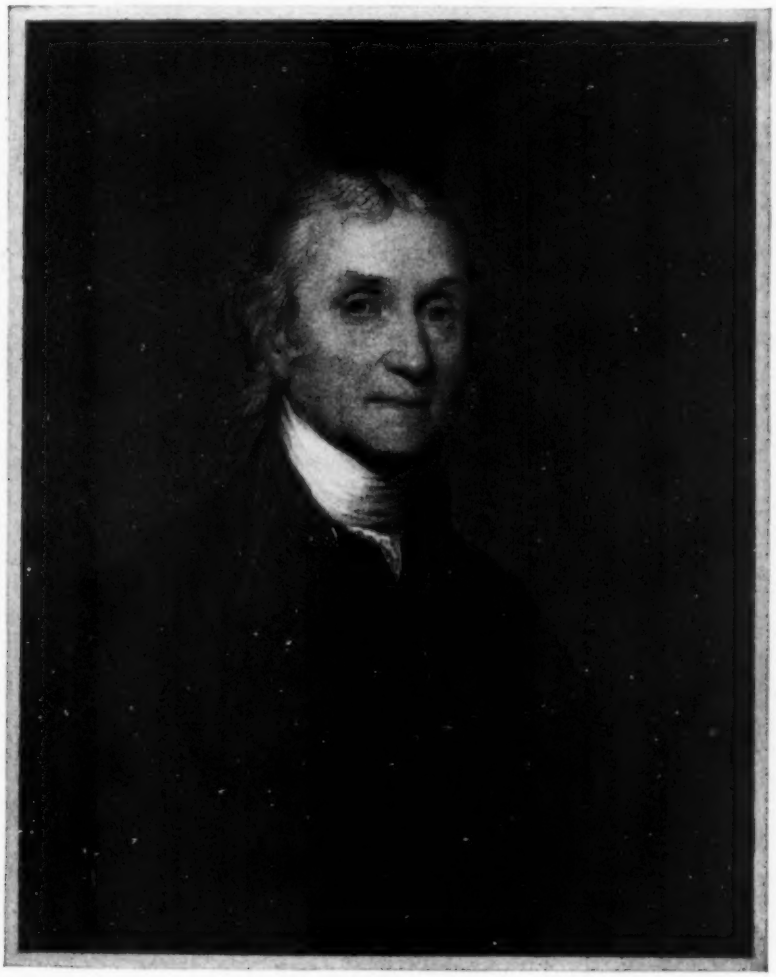
The practical side of this question from a therapeutic view-point appeals to those familiar with throat and lung diseases. For hay fever, asthma and all bronchial affections, not tuberculous, these conditions are ideal, and for patients of this class have already given excellent results. We can not imagine conditions better calculated for the preservation of infant health during the hot summer months, when the rapid atmospheric changes of our cities play such havoc with their powers of resistance to intestinal infections.

We now know the relatively minor rôle that the tubercle bacillus plays in the destruction of the consumptive patient, and the great advantage of placing the early tuberculous process in an air free from dust and the secondary bacterial invaders. We know how injurious to some patients are the climatic changes of a sea voyage, or of the seaside resort, and how badly others react to a change of altitude. Here we have an abundance of cool, pure air rapidly circulating in sunny rooms easily kept at constant conditions of temperature and humidity. Consumptives are not taken at this sanitarium, but I think it is only a question of time when those afflicted with tuberculosis of the air passages may enjoy the benefits to be derived at Luray and other caverns of the world by living in houses modeled after Limair.

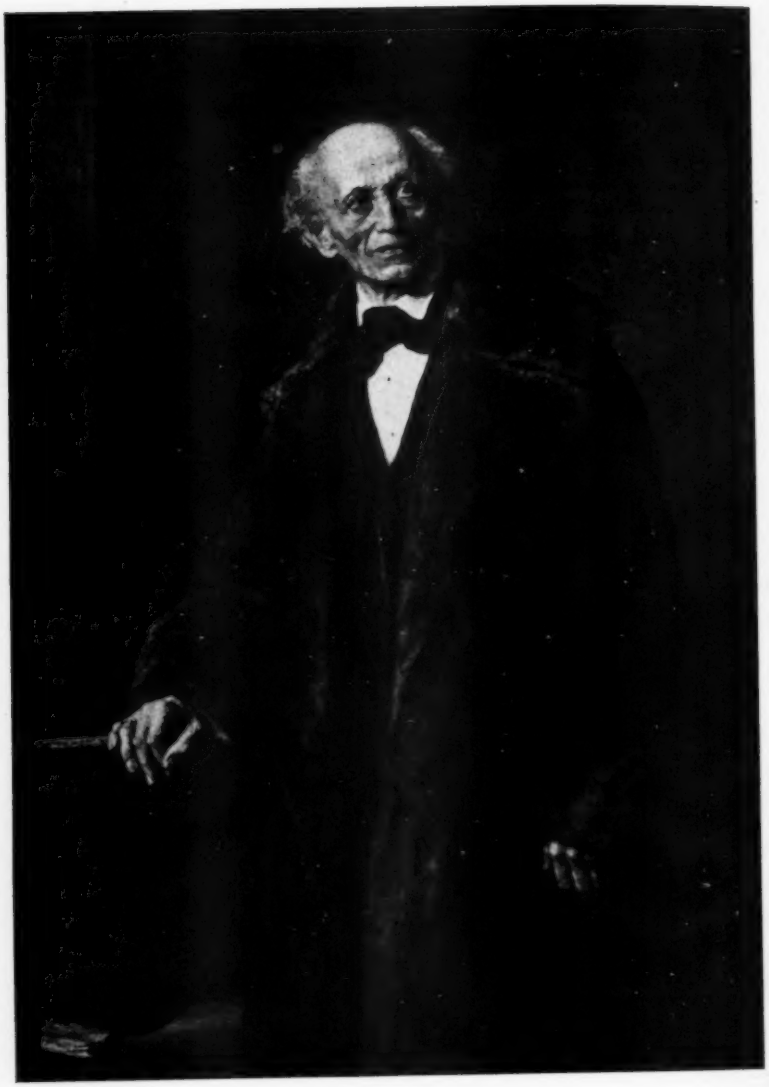
THE PROGRESS OF SCIENCE.

THE CENTENARY OF THE DEATH OF PRIESTLEY.

PRIESTLEY died on February 6, 1804, and the centenary of his death has been commemorated in Great Britain and in the United States. Thirty years ago the centenary of the discovery of oxygen was celebrated, and at that time this magazine published several articles on the life and work of Priestley. In the issue for August, 1874, a biographical sketch and an appreciation by Dr. John W. Draper will be found. An address given by Huxley on the occasion



JOSEPH PRIESTLEY.



PROFESSOR EDUARD ZELLER.

of the presentation of a statue of Priestley to the town of Birmingham is printed in the issue for November, 1874. Priestley's own account of the discovery of oxygen was reprinted in the issue for December, 1900. To these articles those readers may be referred whose attention has been attracted to Priestley by the recent commemoration.

Priestley's discoveries were of epoch-making importance in the history of chemistry; his radical views in politics and theology anticipated in certain directions the course of subsequent thought, and his career is full of dramatic interest, especially to us in America, among whom he took refuge from persecutions at home. Yet it is not often that one of the twenty-five volumes containing Priestley's collected works is taken down from the shelves of the library. The vast range of his controversial writings belongs to the past, and his scientific work was in a sense an episode in his life and in the development of science. But the courage with which he defended what was then heterodoxy in religion and radicalism in political affairs deserves our admiration, and the discovery of oxygen will always remain a landmark in the progress of chemistry.

At the middle of the seventeenth century, chemistry had not yet found its Copernicus or Newton. From our point of view the confusion was extreme. Air, water and fire were regarded as elementary substances. It was supposed that when anything was burned or when an animal breathed, a substance called phlogiston passed into the air and vitiated it. So when Priestley discovered oxygen, he called it dephlogisticated air, it being, 'between five or six times as good as common air.' Priestley did other work of importance in connection with gases, but did not appreciate the real bearings of his own discoveries and can not be placed in the same rank with Cavendish and Laviosier. But he will always be remembered for one of the most important discoveries in the history of science.

PROFESSOR EDUARD ZELLER.

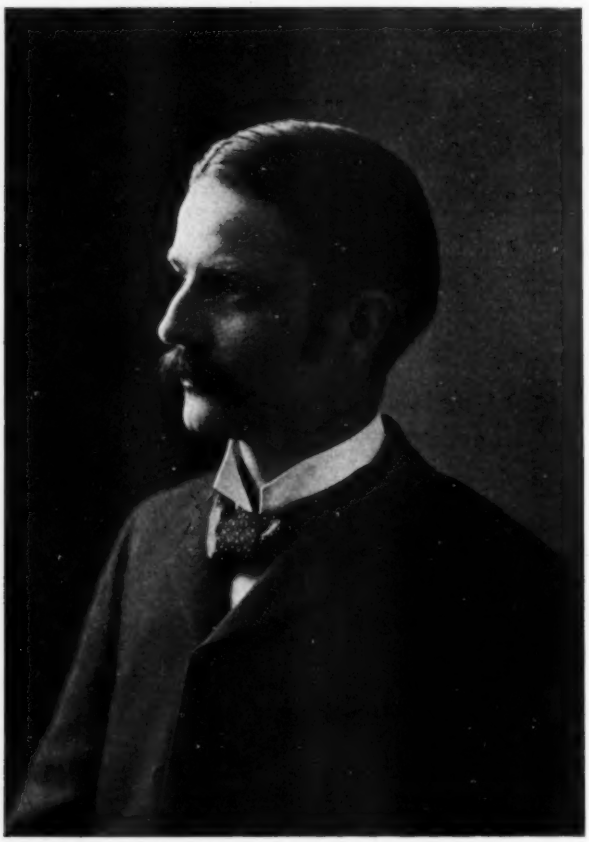
It appears that in Germany, as in England, the great men of the nineteenth century have scarcely bequeathed their genius to their successors. It is quite impossible for Berlin to fill the places vacant by the deaths of Helmholtz, Virchow and Mommsen. One man of that generation the university still has, and it does well to do him honor on his ninetieth birthday. Professor Zeller does not rank with the greatest of his contemporaries, but he represents the highest scholarship, the type which is in danger of submergence beneath the flood of executive work and business detail of modern life.

The work of Professor Zeller carries us a long way back. Starting from the then prevalent Hegelianism, he was one of the first to take a decided stand against the *à priori* construction of the world, and claim that we must go back to the epistemology of Kant and develop it in the light of modern science. But he is best known for his 'Philosophy of the Greeks,' the first volume of which was published sixty years ago. This work has continually been revised for subsequent editions; it was followed in 1872 by a history of German philosophy since Leibnitz and by numerous other publications, especially on the relation of philosophy to science and on the philosophy of religion.

CHARLES EMERSON BEECHER.

Yale University lost only five years ago its eminent paleontologist, Professor O. C. Marsh, and now we are compelled to record the untimely death of his successor, Professor C. E. Beecher, which occurred on February 14, at the age of forty-eight years. Beecher was graduated from the University of Michigan in 1878, and for ten years was assistant to Professor James Hall in the New York Geological Survey. In 1888 he was called to Yale Uni-

versity to take charge of the invertebrate fossils of the Peabody Museum, and received the degree of Doctor of Philosophy in 1889. In 1892 he was made assistant professor and in 1897 professor of historical geology, the title being changed to professor of paleontology in 1902. In 1899 he was elected a member of the National Academy of Sciences. In this year, when he succeeded Professor Marsh as curator of the geological collections, he presented to the museum his collection of fossils, which he had been gathering since he was twelve years old and which contained over 100,000 specimens.

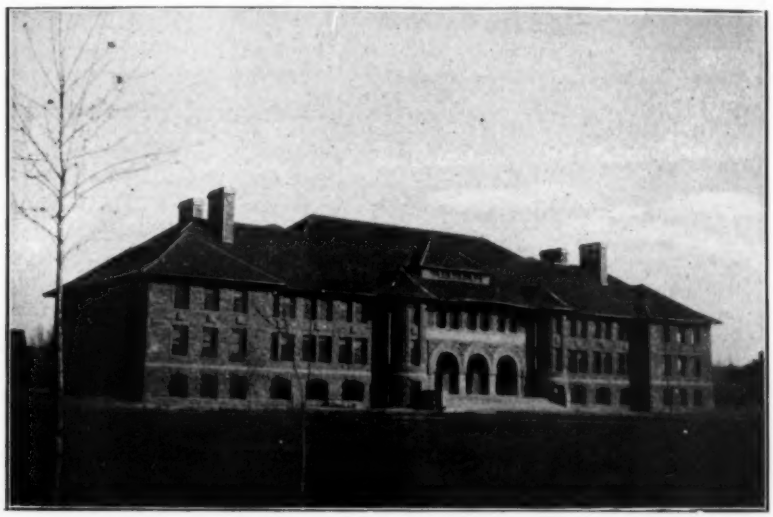


CHARLES EMERSON BEECHER.

Beecher published about sixty papers on invertebrate paleontology, concerned especially with brachiopods and trilobites. He obtained specimens of the latter in which the antennæ and legs were preserved, and made careful studies of the ventral anatomy. He also published a classification of the trilobites, and was at work on an extensive treatise on these primitive crustaceans at the time of his death. Beecher did much work in the field and was skilful in preparing specimens and as a draughtsman. He was also interested in the philosophical aspects of evolution, being counted among the American neo-Lamarckians. In an important paper he finds that species having spines fully developed leave no descendants.

SCIENCE AT COLORADO COLLEGE.

THE state universities of the central and western states have developed with remarkable rapidity, and are now beginning to rival the older institutions of the Atlantic seaboard. It is sometimes said that public support of education interferes with private endowments. But Stanford University and the University of Chicago have been established side by side with the state institutions, and in each case both the state and the private institutions are found to help rather than to interfere with one another. In Colorado in the same way the state university has not in any way prevented the development of Colorado College, and there is every reason to suppose that these institutions will continue to work togther for the educational welfare of the state. In all western institutions, science occupies an important if not a predominant position, and of this the erection of Palmer Hall at Colorado College is significant.



PALMER HALL, COLORADO COLLEGE.

This new building, which was dedicated on February 23, contains provision for the scientific departments and administrative offices of the college. It has received its name in honor of General William J. Palmer, one of the trustees of the institution. As shown in the illustration, the building has three stories; it is built of sandstone with modern fireproof construction. The basement contains laboratories for chemistry, physics and psychology, the first floor, the general offices and lecture rooms and other laboratories for chemistry and physics, and the second floor houses the departments of biology and geology, with the museum.

Nearly ten years ago Dr. D. K. Pearson, to whom American colleges are so greatly indebted, offered to give $50,000 to Colorado College, on condition that a building costing $60,000 should be erected. This money was secured and the building planned, but subsequently larger plans were adopted, and the present building cost nearly $300,000; $30,000 have also been secured for equipment. The dedicatory exercises were carefully planned. President David Starr Jordan, of Stanford University, made the principal address, which we hope to have the privilege of publishing in this magazine. On the

preceding day addresses were made by Dr. C. R. Van Hise, president of the University of Wisconsin, on 'Colorado as a field for scientific research'; by Dr. Samuel L. Bigelow, of the University of Michigan, on 'The growth and function of the modern laboratory'; by Dr. C. E. Bessey, of the University of Nebraska, on 'The possibilities of the botanical laboratory,' and by Dr. Henry Crew, of Northwestern University, on 'Recent advances in the teaching of physics.' The president of the college, Dr. William F. Slocum, said in his address: "We dedicate then to-day this building devoted to the high purposes which led to the founding of the college; to the cause of learning and scientific study, to the up-building of the educational movement throughout the state. It is an added contribution to what other similar institutions are accomplishing in Colorado and throughout our country. In all the years to come may it help to broaden and enlarge the scope of human knowledge and aid in bringing into this section of the United States such a love of the larger life of thought and accurate study, and that new meaning will come to many as they read over its entrance, 'Ye shall know the truth and the truth shall make you free.'"

THE SIZE OF FAMILIES OF COLLEGE GRADUATES.

THE statistics on the size of families of college graduates published last year in this magazine by Professor Thorndike and by Dr. Engelmann have been considerably amplified by President Stanley Hall and Mr. Theodate L. Smith, and form the subject of an article in the last number of *The Pedagogical Seminary*. It is pointed out that the decrease in the number of children per wife is less than per man, owing to the fact that the graduates of the last century so frequently remarried. The conditions for the wives of clergymen in colonial times appear to have been unfortunate, about forty per cent. dying under the age of fifty. But the authors are scarcely justified in saying that 'on this biological blunder of estimating the increase of population per man instead of per woman and too narrow a study of statistics is based much of the alarmist outcry in regard to the future population of the United States.' As far as the increase of the population is concerned, it matters but little whether it is due to strict monogamy or to successive polygamy.

The figures given in the paper are substantially those with which we are familiar. The size of family of the married college graduate has decreased from about four in the first part of the last century to about two and a half in the second half, and at the same time the percentage of those unmarried has increased. Great care must, however, be taken in interpreting such statistics. For example, the members of the class of 1883 of Yale College are reported to have only five living children; but we find that the report relates to a period three years after graduation. Even when the period is as long as fifteen years the number of children will increase by about 50 per cent. The ominous fact stands, however, that college graduates do not now reproduce themselves. If the figures for Harvard College are correct, they are exterminated with startling rapidity, a hundred graduates produce only 68 boys in the next generation, and leave only 30 great-grandsons. It must, however, be remembered that the conditions in the race and class from which graduates come may be as bad. Thus the number of children living for every native Massachusetts woman, between the ages of forty and fifty, was, in 1885, only 1.80.

The statistics for the women graduates are of special interest, although they in most cases relate to such recent classes that they are difficult to interpret. They are also reported by diverse methods and are probably not very accurate. Thus when it is said that of 176 children only 11 have died,

we infer that the deaths have not been reported rather than that the death rate is remarkably low. The only group fifty years of age consists of the first ten classes of Vassar College ending in 1876 with 323 graduates. Fifty-five per cent. had been married as compared with 80 per cent. in the native population, of whom about one third were barren, about twice as many as under normal conditions. The average fertility of those having children is three (including presumably those deceased), which is fully as large as that of the male graduates. The data from later classes are difficult to use. 42.7 per cent. of Smith College graduates prior to 1888 are married and 46.5 per cent. of the Wellesley College graduates. These women are of the average age of over forty years. If only one half of college alumnæ marry and one third of these are barren, while those who have children only reproduce themselves, the 'species' would be completely exterminated in five generations. If colleges for women must be regarded as modern nunneries, there is no special cause for gratification in the fact that in twelve years the number of women students has increased from about 10,000 to about 28,000.

THE STUDY OF THE SCIENCES AND OF LATIN IN THE SECONDARY SCHOOLS.

THERE is annually published in the report of the United States Commissioner of Education an interesting table showing among other things the percentages of students pursuing different studies. The table from the last volume referring to the year 1902 is here reproduced.

It will be noted that the percentage of students studying Latin is recorded as increasing from 38.80 in 1891–92 to 49.52 in 1901–2, whereas in physics there has been a decrease in the same period from 22.04 to 17.39 per cent., and in chemistry from 10.08 to 7.70 per cent. These figures have been widely quoted, and are certainly discouraging to those who are interested in scientific education. It must, however, be remembered that figures are illusive. It has been said that there are three kinds of lies—white lies, black lies and statistics. The figures given in the table are on their face difficult to un-

Students and Studies.	1891-92	1892-93	1893-94	1894-95	1895-96	1896-97	1897-98	1898-99	1899-00	1900-1	1901-2
Males	44.01	43.62	43.39	43.00	43.40	43.84	43.50	42.93	43.16	42.83	42.49
Females	55.99	56.38	56.61	57.00	56.60	56.16	56.50	57.07	56.84	57.17	57.51
Preparing for college, classical course	9.18	9.90	10.34	10.00	10.05	8.94	7.99	7.87	8.32	8.30	6.89
Preparing for college, scientific courses	7.59	8.22	7.33	7.11	7.16	6.57	6.03	6.18	6.21	6.54	5.97
Total preparing for college	16.77	18.12	17.67	17.11	17.21	15.51	14.02	14.05	14.53	14.84	12.86
Graduates	10.87	11.46	11.88	11.60	11.73	11.95	11.75	11.78	11.74	11.95	11.86
Per cent. of graduates prepared for college	39.15	36.62	30.92	32.44	32.69	32.60	30.60	31.61	32.95	33.48	33.67
Studying—											
Latin	38.80	41.94	43.59	43.76	46.22	48.01	49.44	50.29	49.97	49.93	49.52
Greek	4.68	4.92	4.99	4.73	4.58	4.60	4.50	4.27	3.95	3.58	3.36
French	8.59	9.94	10.31	9.77	10.13	9.98	10.48	10.68	10.43	10.75	11.13
German	11.61	13.00	12.78	12.58	13.20	13.76	14.24	14.91	15.06	16.09	16.94
Algebra	47.65	49.92	52.71	52.40	53.46	54.22	55.29	56.21	55.08	55.66	55.27
Geometry	22.52	24.36	25.25	24.51	25.71	26.24	26.59	27.36	26.75	27.26	27.56
Trigonometry	2.96	3.61	3.80	3.25	3.15	3.08	2.83	2.58	2.42	2.54	2.42
Astronomy				5.27	5.19	4.89	4.40	3.94	3.43	2.96	2.64
Physics	22.04	22.25	24.02	22.15	21.85	20.89	20.48	19.97	18.88	18.24	17.39
Chemistry	10.08	9.98	10.31	9.31	9.15	9.18	8.55	8.64	8.00	7.86	7.70
Physical geography				22.44	24.93	24.64	24.33	23.75	22.88	22.42	22.22
Geology				5.52	5.20	4.93	4.66	4.41	4.02	3.88	3.48
Physiology				28.03	31.08	29.98	29.38	28.62	26.96	26.27	24.83
Psychology				3.35	3.82	3.82	3.64	3.23	3.19	2.98	2.53
Rhetoric				31.31	32.27	33.78	35.30	36.70	37.70	39.69	41.90
English literature							38.90	40.60	41.19	43.90	45.60
History (other than United States)	31.35	33.46	35.78	34.65	35.73	36.08	37.68	38.32	37.80	38.41	38.90
Civics							21.41	20.89	21.09	20.60	19.87

derstand, as students are reported as studying on the average 1.8 studies in 1891 and 3.6 studies in 1901. In answer to a request for an explanation of these figures, the U. S. Commissioner of Education has kindly replied as follows:

I have your letter of recent date referring to the remarkable increase in the numbers of students in certain studies in the high schools since 1890. When this office began to classify the statistics of secondary schools more than fifteen years ago it was found that many schools had been reporting a large percentage of elementary pupils as in the high schools when in fact they pursued no secondary studies. It required several years to devise a form of inquiry which would enable this office to eliminate the elementary pupils.

It is probable that in 1890 a pupil was reported as a secondary student if he had *one* or more secondary studies. Now he must have at least *two* secondary studies to be so classed. (See marked form herewith.) Every year we are able to get a better classification and by insisting on answers to question 14 (the studies pursued) we are able to eliminate the elementary pupils. The classification was not so close in 1890.

We now state in our summaries *how many* schools reported students in certain studies (see page 1652, report for 1902 sent under another cover). This was not done in 1890.

The three-and a half subjects studied (the average mentioned in your letter) is not excessive. In many schools the minimum required is four subjects each year.

If the fact that students were reported in 1891 as studying on the average less than two subjects was because certain elementary pupils taking only one study were included and if high school students on the average pursue four studies, it would follow that about 70 per cent. of all students reported in the high schools were elementary students. This was of course not the case, and with the data at hand we can only conclude that in 1891 the studies pursued by many students were not reported, and that we do not know what percentage of students studied Latin at that time. It may have been 60 per cent. The percentage of students studying Latin has probably decreased, because relatively more students are now prepared for the college scientific course than for the classical course, while at the same time the percentage of graduates entering college has decreased. The percentage reported as studying Latin has decreased since 1898 when the figures may be assumed to have become more accurate.

The decrease in the number of students studying physics and chemistry is not, however, so easily explained away. It may be that in 1891 elementary students taking physics or chemistry were reported, whereas but few elementary students would take Latin. The percentage of girls has increased, and this would favor literary as compared with scientific studies. The figures for zoology and botany are not given, and in the increase of the number of studies open to secondary students, there would naturally be a decrease in the number studying each subject. Still there is reason to believe that physics and chemistry as taught in the high school and college are not attractive to students. Indeed, we have grounds for fear that the high school course as a whole is not as useful as it should be, especially for boys. The figures given in the table show that 42.49 per cent. of secondary students are boys, whereas the boys graduating from the high school are only 34 per cent. of the total number. Only about 20 per cent. of students—boys and girls—entering the high school stay to graduate, and in Boston only 10 per cent. of the boys who enter the high school remain as long as the fourth year.

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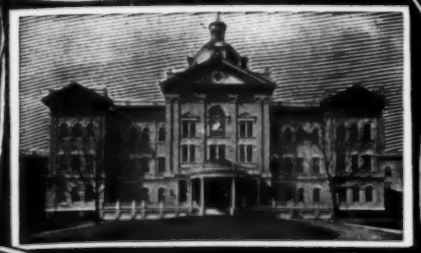

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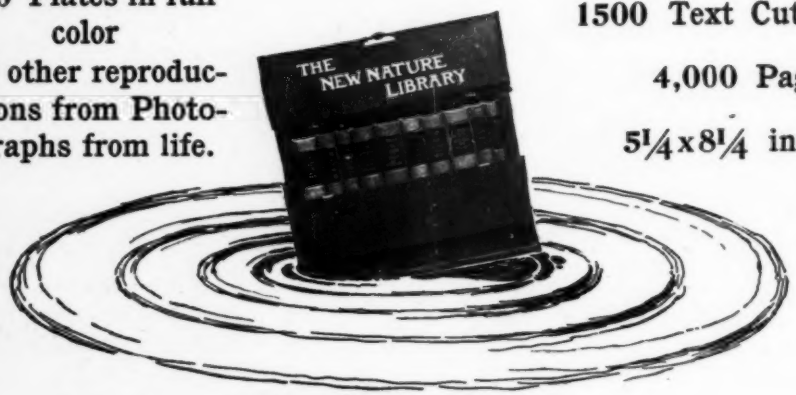

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